

SUPPLEMENTO  
AL VOLUME XII, SERIE IX, DEL  
**NUOVO CIMENTO**  
A CURA DELLA SOCIETÀ ITALIANA DI FISICA

1954

N. 3

**Sezioni d'urto elastico protone-protone e neutrone-protone.**

L. BERETTA e C. VILLI (\*)

*Istituto di Fisica dell'Università - Trieste*

F. FERRARI (+)

*Istituto di Fisica dell'Università - Padova*

*Istituto Nazionale di Fisica Nucleare - Sezione di Padova*

(ricevuto il 18 Maggio 1954)

SOMMARIO: A) Urto elastico protone-protone. B) Urto elastico neutrone-protone.

Ci proponiamo in questo lavoro di presentare una sintesi dei dati sperimentali relativi alla diffusione elastica protone-protone e neutrone-protone. I valori sperimentali delle sezioni d'urto, che sono dati tanto nel sistema del laboratorio quanto in quello del centro di massa, sono raggruppati nel modo seguente:

*Sezioni d'urto differenziali protone-protone:*

Energia: 0,17-0,60 MeV - Tabelle Ia, Ib, Ic: Grafico I.

» 0,60-2,00 MeV - Tabelle IIa, IIb, IIc, IIId, IIe, IIIf; Grafico II.

» 2,00-5,50 MeV - Tabelle IIIa, IIIb, IIIc, IIId, IIIe, IIIf, IIIg;  
Grafico III.

» 5,50-32,0 MeV - Tabelle IVa, IVb, IVc, IVd, IVe, IVf, IVg,  
IVh, IVi; Grafico IV.

» 32,0-435 MeV - Tabelle Va, Vb, Vc, Vd, Ve, Vf, Vg, Vh;  
Grafico V.

(\*) Attualmente presso il Department of Mathematical Physics, University of Birmingham, Inghilterra.

(+) Attualmente presso il Max-Planck-Institut für Physik, Göttingen, Germania.

*Sezioni d'urto totali protone-protone:*

Energia: 225-435 MeV - Tabella F.

*Sezioni d'urto differenziali neutrone-protone:*Energia 3-260 MeV - Tabelle VIa, VIb, VIc, VI $\bar{d}$ , VIe, VI $\bar{f}$ , VIg;  
Grafico VI.*Sezioni d'urto totali neutrone-protone:*

Energia: 0,01-400 MeV - Tabella VII; Grafico VII.

Nei grafici 1, 2, 3, 4, 5 sono rappresentati gli andamenti delle sezioni d'urto differenziali protone-protone e neutrone-protone in funzione dell'energia, per i seguenti valori dell'angolo di diffusione (sistema del centro di massa):  $\Theta = 20^\circ$ ,  $\Theta = 30^\circ$ ,  $\Theta = 40^\circ$ ,  $\Theta = 60^\circ$ ,  $\Theta = 90^\circ$ .

Le curve tracciate nei grafici hanno solo significato indicativo.

**A) Urto elastico protone-protone.**

*Sezione d'urto differenziale.* - Le prime ricerche in questo campo risalgono al 1935, quando WELLS [A 1], osservando in camera di Wilson tracce prodotte da protoni, constatò degli urti anomali non interpretabili con la formula teorica di Mott. Risultava così confermata l'ipotesi della esistenza di forze non elettriche, a corto raggio d'azione, esercitanti fra protoni.

Da allora l'urto protone-protone fu oggetto di numerose esperienze aventi lo scopo di misurare la distribuzione angolare delle particelle diffuse.

WHITE [A 2], TUVE [A 3], HAFSTAD [A 4], RAGAN e coll. [A 8] danno il rapporto fra la sezione d'urto sperimentale e quella di Mott, per diversi angoli di diffusione e per energie comprese fra 0,17 e 0,9 MeV (Tabelle A, B, C, D). Da questi dati si ottiene una sezione d'urto (Tabelle Ia, Ib, Ic; Grafico I) che, per  $\Theta = 90^\circ$ , tende a diminuire fortemente nell'intervallo energetico 0,32-0,45 MeV; questo fatto trova conferma nei recenti lavori di ZIMMERMANN e coll. [A 45] [A 50] (Grafico 5).

HERB [A 5] [A 6], HEIDENBURG e coll. [A 7], usando come diffusore idrogeno gassoso e come rivelatori camere di ionizzazione, hanno eseguito diverse misure con protoni di energie comprese fra 0,6 e 2 MeV; i risultati sono in accordo sia con quelli calcolati in base ai precedenti rapporti  $\sigma_{\text{sper}}/\sigma_{\text{Mott}}$ , sia con quelli recentemente ottenuti da WORTHINGTON e coll. [A 44] mediante contatori proporzionali (Tabelle IIa, IIb, IIc, II $\bar{d}$ , IIe, II $\bar{f}$ ; Grafico II).

Nell'intervallo 2-32 MeV le esperienze sono state eseguite, raccogliendo i protoni diffusi in idrogeno gassoso, con lastre nucleari da MAY e POWELL [A 13], da ROUVINA [A 27], da DEARNLEY [A 15], da MEAGHER [A 20], da MATHER



[A 28], da FILLMORE [A 21] [A 35], da ALLRED [A 40], da KERMAN e coll. [A 41]; con contatori proporzionali da SLEATOR [A 14], da BLAIR [A 16] [A 17], da ZIMMERMAN [A 30], da BONDELID [A 18] [A 39], da YNTEMA [A 42], da WORTHINGTON [A 44], da CORK e coll. [A 22] [A 25]; con camera di ionizzazione da HERB [A 45] e da WILSON e coll. [A 9] [A 10] [A 11] [A 12]. Singoli valori a  $90^\circ$ , in accordo con i precedenti, sono stati ottenuti da FARIS (lastre nucleari) [A 24] a 12,4 MeV e da CORK e coll. (contatori proporzionali) [A 25] a 18,8-22,2, 25,45, 31,8 MeV.

Nel complesso la sezione d'urto risulta in questo intervallo energetico ben definita (Tabelle IIIa, IIIb, IIIc, IIId, IIIe, IIIf, IIIg; Grafico III e Tabelle IVa, IVb, IVc, IVd, IVe, IVf, IVg, IVh, IVi; Grafico IV).

Per energie maggiori di 32 MeV, la situazione sperimentale si presenta piuttosto incerta. Le misure eseguite da BIRGE [A 32] a 75 e 100 MeV, da TOWLER [A 36] [A 38] e da OXLEY [A 37] a 240 MeV, da CASSELS [A 33] e da CHAMBERLAIN [A 26] [A 31] [A 34] a 250 e 345 MeV, da MARSHALL e coll. [A 49] a 429 MeV indicano delle sezioni d'urto praticamente costanti al variare dell'angolo di diffusione da  $30^\circ$  a  $90^\circ$ ; KRUSE e coll. [A 51] osservano invece, a 95 MeV, una lenta diminuzione e SUTTON e coll. [A 43] [A 53] [A 54], a 435 MeV, una diminuzione decisamente più rapida. Per quanto riguarda i valori assoluti delle sezioni d'urto, è da notare che i dati di KRUSE [A 51] a 95 MeV non si accordano con quelli di BIRGE [A 32] a 75 e 100 MeV e che quelli di CHAMBERLAIN [A 19] [A 23] a 340 MeV sono troppo alti rispetto ai valori trovati a 345 MeV da SEGRÈ [A 26] [A 31]. Inoltre SEGRÈ (\*) [A 26] [A 34] e MARSHALL [A 46] [A 49] osservano una sezione d'urto costante al variare dell'energia da 120 a 350 MeV, il cui valore però non si accorda con quello di CASSELS [A 33] a 146 MeV e con quelli di OXLEY [A 29] [A 37] e di TOWLER e coll. [A 36] [A 38] a 240 MeV (Tabelle Va, Vb, Vc, Vd, Ve, Vf, Vg, Vh; Grafico V; Tabella E). Le misure sono state eseguite con diffusori solidi o liquidi e usando come rivelatori in prevalenza contatori a scintillazione. In particolare, hanno usato polietilene e contatori a scintillazione BIRGE [A 32], CHAMBERLAIN [A 26] [A 31] [A 34], MOTT e coll. [A 43]; polietilene e contatori proporzionali CHAMBERLAIN e coll. [A 19] [A 23]; idrocarburi e lastre TOWLER e coll. [A 36] [A 38]; idrocarburi e contatori a scintillazione OXLEY e coll. [A 37]; idrogeno liquido e contatori a scintillazione CHAMBERLAIN e coll. [A 26] [A 34]; idrogeno liquido e contatori proporzionali KANE e coll. [A 53] e SUTTON e coll. [A 54].

*Sezione d'urto totale.* — Singole esperienze, di notevole importanza agli effetti del confronto fra l'urto protone-protone e neutrone-protone, sono state eseguite

---

(\*) Misure eseguite recentemente da E. SEGRÈ e coll. confermano i valori assoluti della sezione d'urto già trovati dagli stessi Autori. Questi valori sono però in disaccordo con quelli di Rochester e Harwell. Siamo grati al prof. SEGRÈ per questa comunicazione.



onde misurare la sezione d'urto totale protone-protone. MARSHALL e coll. [A 46] [A 49], integrando la sezione d'urto differenziale dopo averla estrapolata a  $\Theta = 0^\circ$ , CLARK [A 48], SHAPIRO [A 45], CHAMBERLAIN e coll. [A 56], con un metodo di trasmissione simile a quello usato per la determinazione della sezione d'urto totale neutrone-protone, trovano per energie comprese tra 225 e 435 MeV delle sezioni d'urto totali leggermente inferiori a quelle relative all'urto neutrone-protone. I risultati sono raccolti nella tabella F.

## B) Urto elastico neutrone-protone.

*Sezione d'urto differenziale.* — La determinazione della sezione d'urto differenziale neutrone-protone è particolarmente laboriosa a causa della difficoltà connessa alla misura assoluta dell'intensità dei fasci neutronici. Molti Autori si limitano pertanto a dare la distribuzione angolare dei protoni diffusi da neutroni in idrogeno gassoso.

Tra questi, MODON-HERTZEN [B 2], DEE [B 11], KRUGER [B 6], BONNER e coll. [B 8], studiando l'urto neutrone-protone in camera di WILSON; TATEL [B 33], BARSHALL e coll. [B 26], usando come rivelatori camere di ionizzazione, ottengono per energie intorno ai 2,5 MeV una distribuzione angolare che presenta, nel sistema del centro di massa, simmetria sferica. Alle stesse energie danno invece una distribuzione angolare non uniforme KURIE [B 1], HARKINS [B 3] (camera di Wilson), WAKATSUKI e coll. [B 18] (camera di ionizzazione). Per energie comprese fra 7 e 24 MeV, trovano simmetria sferica POWELL [B 28] [B 31], LAUGHLIN e coll. [B 54] [B 48], osservando le tracce dei protoni di rinculo, rispettivamente, in emulsioni nucleari ed in camera di Wilson; TATEL [B 33], BARSHALL [B 26], BALDWIN e coll. [B 63], usando come rivelatori, rispettivamente, una camera di ionizzazione ed un telescopio di contatori proporzionali in coincidenza. Con quest'ultimo metodo, AMALDI [B 32] [B 35] [B 36] misura invece, nell'intervallo energetico 12-14 MeV, fra i protoni diffusi a  $90^\circ$  e  $180^\circ$ , un rapporto prossimo a 0,5.

Per una energia media di 90 MeV, BRUECKNER e coll. [B 52], studiando l'urto in camera di Wilson e SHAL [B 78], raccogliendo con dei contatori a scintillazione i protoni diffusi dal fascio neutronico in idrogeno liquido, confermano una distribuzione angolare non uniforme.

Valori assoluti della sezione d'urto differenziale sono dati da ODA e coll. [B 58] a 3,1 MeV, da BROLLEY e coll. [B 62] a 27 MeV, da HADLEY [B 49] [B 51], da WALLACE [B 60] e da SELOVE e coll. [B 76] a 40 e 90 MeV, da MOTT e coll. [B 69] a 172 e 215 MeV, da KELLY e coll. [B 55] a 260 MeV. Le sezioni d'urto da essi trovate non presentano simmetria sferica. (Tabelle VIa, VIb, VIc, VI<sub>d</sub>, VIe, VI<sub>f</sub>, VI<sub>g</sub>; Grafico VI). ODA e coll. [B 58] hanno eseguito le misure usando come diffusore H<sub>2</sub>O o paraffina e come rivelatore camere di ionizzazione;



BROLLEY [B 62], HADLEY e coll. [B 49] [B 51] idrogeno gassoso e contatori proporzionali; WALLACE e coll. [B 60] idrogeno gassoso ed emulsioni nucleari; SELOVE [B 76]  $H_2O$  e contatori a scintillazione; MOTT e coll. [B 69] polietilene e contatori a scintillazione; KELLY e coll. [B 55] polietilene e contatori proporzionali.

*Sezione d'urto totale.* — La sezione d'urto totale è stata studiata misurando il rapporto tra le intensità dei fasci trasmesso ed incidente. A causa della difficoltà di ottenere fasci monoenergetici di basse energie, essa risulta poco precisa per energie inferiori al MeV.

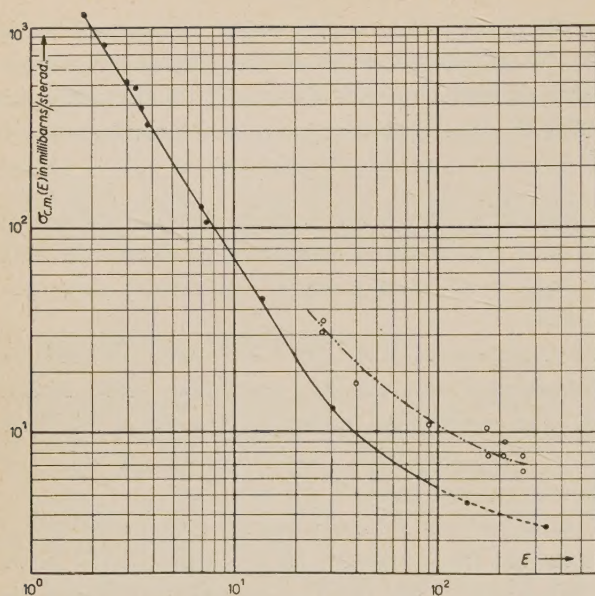
FEDOROV e coll. [B 10] e GOLOBORODKO [B 22] [B 37] trovano per neutroni termici, di energia non perfettamente determinata, un valore della sezione d'urto di  $5,0 \pm 0,1$  millibarn. Per un'energia compresa fra 0,6 e 1,2 MeV, TUVE e coll. ottengono i valori 4,7 e 3,7 millibarn. AMALDI e coll. [B 17] [B 21] trovano il valore di 3,3 millibarn per neutroni di 0,1-0,2 MeV.

Valori della sezione d'urto totale per energie comprese fra 0,01 e 400 MeV (\*) sono stati ottenuti da LANDENBURG [B 7], BOOTH [B 9], AOKI [B 13] [B 14] [B 15] [B 18], ZINN [B 12] [B 20], GOOD [B 25] [B 27], LEIPUNSKI [B 19] [B 29], SLEATOR [B 39] [B 46], BAILEY [B 40], DE JUREN [B 54] [B 57] [B 59], ODA e coll. [B 58], misurando l'intensità dei fasci con camere di ionizzazione; da AMALDI [B 24], FRISH [B 41] [B 42], AGENO [B 43], WATTENBERG [B 44], KELLY [B 55], LASDLAY [B 61], BROLLEY [B 62], TAYLOR [B 64], [B 65], FIELDS [B 73], NEDZEL e coll., [B 74] con contatori proporzionali; da FOX [B 56], POSS [B 66] [B 67], MOTT [B 68], GOODMAN [B 70], COON [B 71], HAFNER [B 72], DAY [B 75], TAYLOR e coll., [B 77] con contatori a scintillazione; da SALANT [B 16] [B 23], SHERR [B 34] [B 38], COOK [B 47] [B 50], LAMPI e coll. [B 53], misurando con metodi indiretti il rapporto fra le intensità dei due fasci. Come sostanze diffondenti, è stata data preferenza, per ovvie ragioni sperimentali, a quelle liquide e solide: paraffina [B 7] [B 12] [B 13] [B 15] [B 16] [B 17] [B 20] [B 21] [B 23] [B 25] [B 34] [B 38] [B 39] [B 44] [B 46] [B 47] [B 56] [B 58], polietilene [B 41] [B 42] [B 53] [B 55] [B 61] [B 64] [B 65] [B 66] [B 67] [B 68] [B 72] [B 77], idrocarburi [B 40] [B 54] [B 57] [B 59] [B 73] [B 74], acqua [B 12] [B 22] e idrogeno liquido [B 78]; solo poche esperienze sono state eseguite usando idrogeno gassoso [B 43] [B 63] [B 71] [B 75].

Ringraziamo i proff. N. DALLAPORTA e G. PUPPI per alcune discussioni sull'argomento. Siamo grati inoltre all'ing. F. GRANCINI e al sig. G. VASCOTTO per l'aiuto prestatoci nell'esecuzione dei grafici.

---

(\*) I valori della sezione d'urto totale per neutroni lenti sono riportati nel *Velocity Columbia Selector in The Science and Engineering of nuclear power* (Cambridge, 1947), pag. 394.



**Sezioni d'urto differenziali  
protone-protone e neu-  
trone-protone**

Grafico 1. - ( $\Theta = 20^\circ$ ).

● Valori sperimentali della  
sezione d'urto differen-  
ziale protone-protone.

○ Valori sperimentali della  
sezione d'urto differen-  
ziale neutrone-protone.

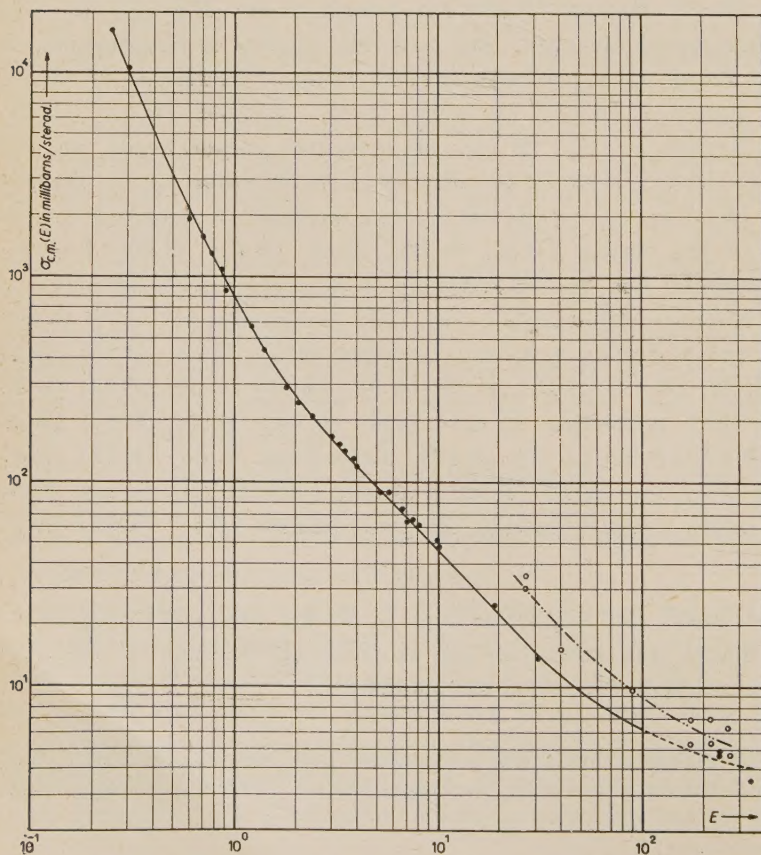


Grafico 2.

( $\Theta = 30^\circ$ )

● Valori sperimentali della sezione d'urto differenziale protone-protone.

○ Valori sperimentali della sezione d'urto differenziale neutrone-protone.



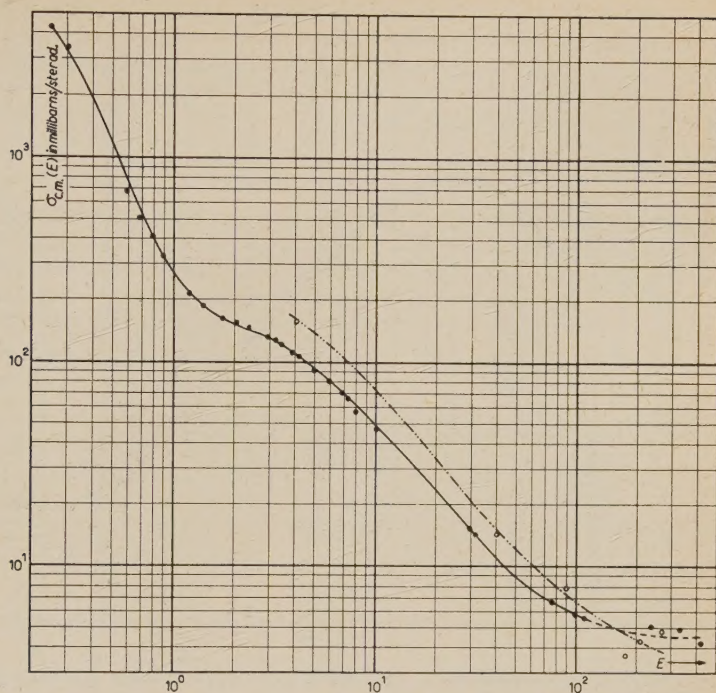


Grafico 3.  
( $\theta = 40^\circ$ )

- Valori sperimentali della sezione d'urto differenziale protone-protone.
- Valori sperimentali della sezione d'urto differenziale neutrone-protone.

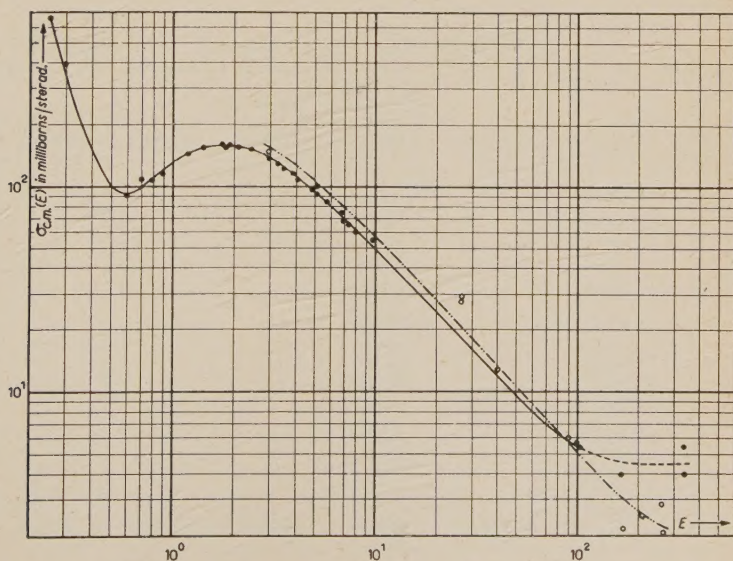


Grafico 4.  
( $\theta = 60^\circ$ )

- Valori sperimentali della sezione d'urto differenziale protone-protone.
- Valori sperimentali della sezione d'urto differenziale neutrone-protone.

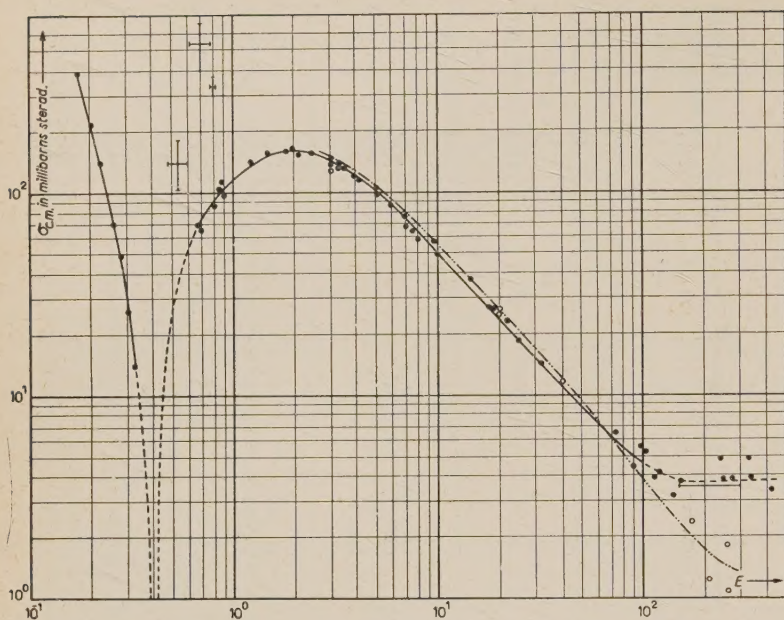


Grafico 5.  
( $\Theta = 90^\circ$ )

- Valori sperimentali della sezione d'urto differenziale protone-protone.
- Valori sperimentali della sezione d'urto differenziale neutrone-protone.



## Valori del rapporto fra la sezione d'urto sperimentale e quella di Mott.

TABELLA A. - *Energia* = 0,3 - 0,8 MeV [A2].

$\vartheta$	$\Theta$	$\sigma_{\text{Sper}}(\Theta)/\sigma_{\text{Mott}}(\Theta)$			
Energia		0,30 - 0,45	0,45 - 0,60	0,60 - 0,75	0,75 - 0,80
10° - 15°	20° - 30°	0,3	0,3	0,2	0,2
15° - 20°	30° - 40°	0,8	0,7	0,6	0,8
20° - 25°	40° - 50°	0,4	0,6	1,3	1,3
25° - 30°	50° - 60°	0,9	1,8	0,6	0,0
30° - 35°	60° - 70°	0,8	1,9	1,0	0,7
35° - 40°	70° - 80°	0,0	1,4	5,8	3,8
40° - 45°	80° - 90°	0,0	1,8	10,8	10,0

TABELLA B. - *Energia* = 0,6 - 0,9 MeV [A3].

$\vartheta$	$\Theta$	$\sigma_{\text{Sper}}(\Theta)/\sigma_{\text{Mott}}(\Theta)$			
Energia		0,600	0,700	0,800	0,900
15,0°	30°	0,64	0,71	0,73	0,62
20,0°	40°	0,68	0,72	0,73	0,71
25,0°	50°	0,61	0,73	0,78	0,91
27,5°	55°	—	—	0,83	1,06
30,0°	60°	0,53	0,83	1,02	1,43
32,5°	65°	—	1,03	1,31	1,76
35,0°	70°	0,61	1,22	1,57	2,49
37,5°	75°	—	1,26	1,84	3,38
40,0°	80°	0,57	1,48	2,36	3,66
42,5°	85°	—	1,61	2,59	4,04
45,0°	90°	—	1,52	2,55	3,88

TABELLA C. - *Energia* = 0,17 - 0,32 MeV [A8].

$\vartheta$	$\Theta$	$\sigma_{\text{Sper}}(\Theta)/\sigma_{\text{Mott}}(\Theta)$						
Energia		0,1765	0,2002	0,2259	0,2495	0,2753	0,2980	0,3214
15,0°	30°	—	—	—	0,929	—	0,861	—
20,0°	40°	—	—	—	0,865	—	0,808	—
22,5°	45°	—	—	—	0,836	—	—	—
25,0°	50°	—	—	—	0,769	—	0,737	—
27,5°	55°	—	—	—	0,723	—	—	—
30,0°	60°	—	—	—	0,674	—	0,570	—
32,5°	65°	—	—	—	0,606	—	0,507	—
35,0°	70°	—	—	—	0,506	—	0,390	—
37,5°	75°	—	—	—	0,401	—	0,319	—
40,0°	80°	—	—	—	0,335	—	0,217	—
42,5°	85°	—	—	—	0,275	—	0,142	—
45,0°	90°	0,544	0,448	0,353	0,256	0,177	0,118	0,070

TABELLA D. — *Energia* — 0,220 – 0,640 MeV [A4].

$\vartheta$		$\sigma_{\text{Sper}}(\Theta)/\sigma_{\text{Mott}}(\Theta)$									
Energia		0,220		0,335		0,450		0,550		0,640	
$\sigma_{\text{Sper}}(50^\circ)$		1)	2)	1)	2)	1)	2)	1)	2)	1)	2)
$\sigma_{\text{Mott}}(50^\circ)$		1,00	0,87	1,00	0,75	1,00	0,61	1,00	0,58	1,00	0,56
20°	40°	—	—	—	—	—	—	—	—	1,01	0,57
25°	50°	1,00	0,87	1,00	0,75	1,00	0,61	1,00	0,58	1,00	0,56
30°	60°	0,95	0,83	0,86	0,64	0,76	0,46	0,86	0,50	0,95	0,53
35°	70°	0,90	0,78	0,65	0,49	0,48	0,29	0,73	0,42	0,95	0,53
40°	80°	0,81	0,70	0,45	0,34	0,23	0,14	0,53	0,31	1,26	0,71
45°	90°	0,51	0,44	0,33	0,25	0,058	0,03	0,44	0,25	1,71	0,96
50°	100°	0,30	0,26	0,40	0,30	0,23	0,14	—	—	0,96	0,54
55°	110°	0,10	0,09	0,34	0,26	0,44	0,27	—	—	—	—
60°	120°	—	—	—	—	—	—	—	—	0,97	0,54

I rapporti sono stati ottenuti per confronto con quelli calcolati teoricamente a  $\vartheta = 25^\circ$ ,  $\Theta = 50^\circ$ , 1) trascurando l'effetto nucleare, 2) tenendone conto.

**Valori medi sperimentali della sezione d'urto differenziale protone-neutrone nel sistema del centro di massa.**

TABELLA E. — *Energia* = 146 – 429 MeV.

Energia	146[A33]	150-350[A46]	225[A56]	240[A29]	330[A56]	429[A49]
$\Theta$	$\sigma_{\text{c.m.}}(\Theta)$ in mb/ster.					
18°-19°	—	—	$3,56 \pm 0,15$	—	$3,72 \pm 0,15$	—
27°-90°	—	—	—	$4,5 \pm 0,5$	—	—
28°-90°	—	—	—	—	—	3,3
20°-90°	$4,86 \pm 0,25$	—	—	—	—	—
90°	—	$3,5 \pm 0,4$	—	—	—	—

**Valori sperimentali della sezione d'urto totale protone-protone.**

TABELLA F. — *Energia* = 225 – 435 MeV.

Energia	Bibliografia	$\sigma_{\text{tot}}$ in mb
225	[A 56]	$22,07 \pm 0,93$
330	[A 56]	$23,06 \pm 0,93$
408	[A 46]	$24,0 \pm 1,0$
410	[A 55] (*)	27
429	[A 49]	24,2
435	[A 48]	$27,5 \pm 5,0$

(\*) A. M. Shapiro e coll. (A55) hanno eseguito misure di sezione d'urto totale protone-protone anche per energie maggiori di 410 MeV. Per queste energie è però già sensibile l'effetto degli urti anelastici.



## Valori sperimentali della sezione d'urto differenziale protone-protone.

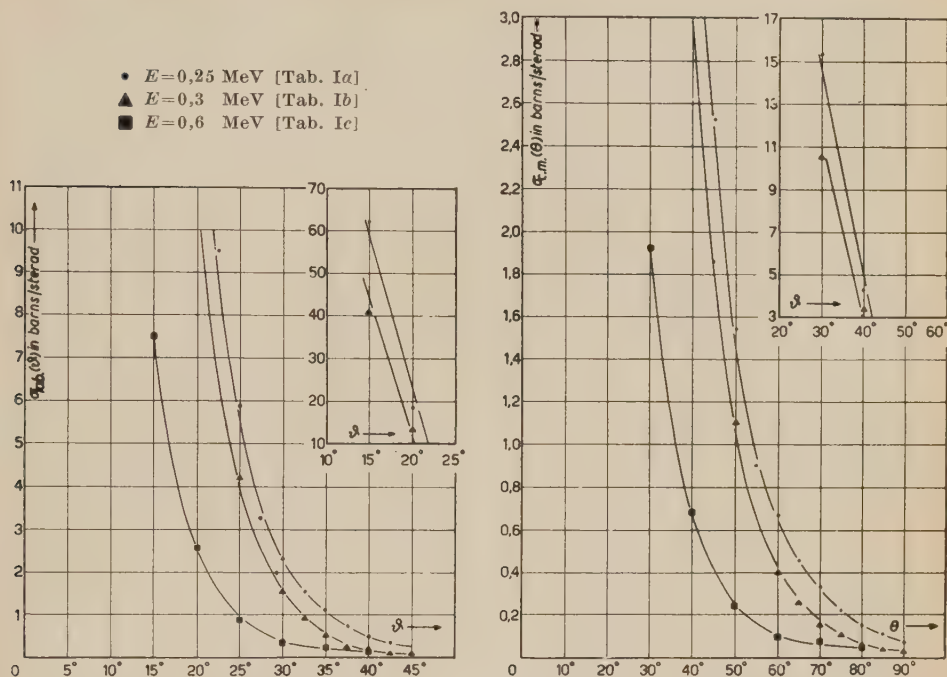


Grafico I. - Sezione d'urto differenziale protone-protone nel sistema del laboratorio  $\sigma_{lab}(\theta)$  e in quello del centro di massa  $\sigma_{c.m.}(\Theta)$ .

TABELLA Ia. - Energia = 0,175 - 0,275 MeV [A<sup>8</sup>].

Energia	0,1765	0,2002	0,2259	0,2495	0,2753	Energia	0,1765	0,2002	0,2259	0,2495	0,2753
$\theta$	$\sigma_{lab}(\theta)$ in mb/ster.					$\Theta$	$\sigma_{c.m.}(\Theta)$ in mb/ster.				
15,0°	—	—	—	63 000	—	30°	—	—	—	16 257	—
20,0°	—	—	—	16 900	—	40°	—	—	—	4 325	—
22,5°	—	—	—	9 500	—	45°	—	—	—	2 508	—
25,0°	—	—	—	5 918	—	50°	—	—	—	1 538	—
27,5°	—	—	—	3 218	—	55°	—	—	—	904	—
30,0°	—	—	—	2 345	—	60°	—	—	—	674	—
32,5°	—	—	—	1 525	—	65°	—	—	—	454	—
35,0°	—	—	—	1 079	—	70°	—	—	—	329	—
37,5°	—	—	—	695	—	75°	—	—	—	220	—
40,0°	—	—	—	465	—	80°	—	—	—	151	—
42,5°	—	—	—	326	—	85°	—	—	—	110	—
45,0°	1 082	606	400	199	134	90°	381	217	141	70	48

TABELLA Ib. (\*)

 $Energia = 0,2980 - 0,3214 \text{ MeV}^{[A8]}$ .

TABELLA Ic.

 $Energia = 0,600 \text{ MeV}^{[A3]}$ .

Energia	0,2980	0,3214	Energia	0,600
$\vartheta$	$\sigma_{lab}(\vartheta)$ in mb/ster.		$\vartheta$	$\sigma_{lab}(\vartheta)$ in mb/ster.
15,0°	41 100	—	15,0°	7 450
20,0°	13 312	—	20,0°	2 557
25,0°	4 203	—	25,0°	874
30,0°	1 476	—	30,0°	317
32,5°	940	—	32,5°	—
35,0°	500	—	35,0°	240
37,5°	231	—	37,5°	—
40,0°	183	—	40,0°	129
42,5°	102	—	42,5°	—
45,0°	73	40	45,0°	—
$\Theta$	$\sigma_{c.m.}(\Theta)$ in mb/ster.		$\Theta$	$\sigma_{c.m.}(\Theta)$ in mb/ster.
30°	10 537	—	30°	1 920
40°	3 421	—	40°	680
50°	1 106	—	50°	240
60°	399	—	60°	91
65°	254	—	65°	—
70°	156	—	70°	73
75°	105	—	75°	—
80°	59	—	80°	45
85°	35	—	85°	—
90°	26	14	90°	—

(\*) Cfr. Appendice.



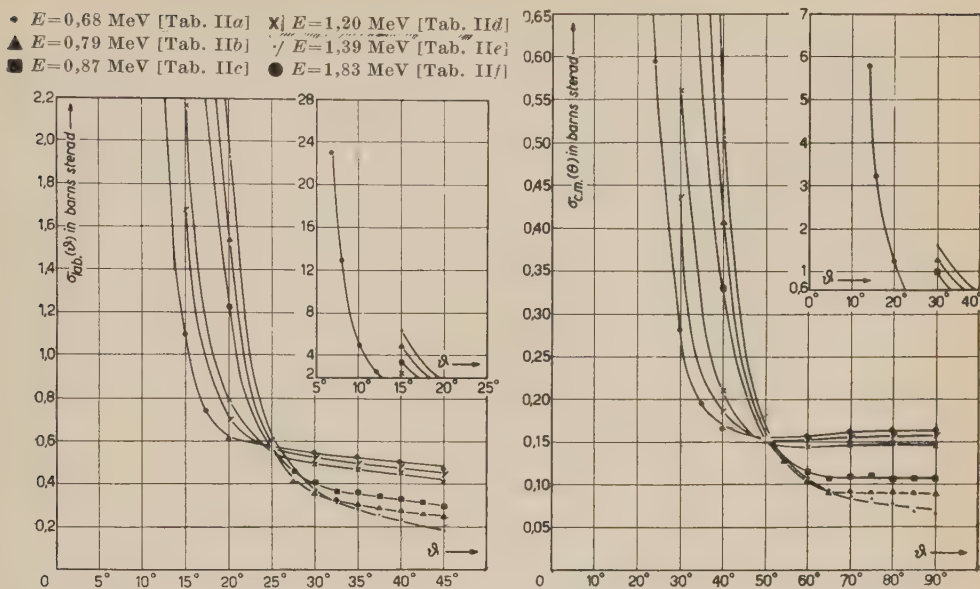


Grafico II. - Sezione d'urto differenziale protone-protone nel sistema del laboratorio  $\sigma_{\text{lab}}(\theta)$  e in quello del centro di massa  $\sigma_{\text{c.m.}}(\Theta)$ .

TABELLA IIa. - Energia = 0,67 - 0,70 MeV.

Energia	0,67 [A7]	0,67 [A7]	0,70 [A3]	Energia	0,67 [A7]	0,67 [A7]	0,70 [A3]
$\theta$	$\sigma_{\text{lab}}(\theta)$ in mb/ster.			$\Theta$	$\sigma_{\text{c.m.}}(\Theta)$ in mb/ster.		
15,0°	—	—	6 208	30°	—	—	1 597
20,0°	1 867,60	1 936,98	1 965	40°	496,86	522,51	504
25,0°	650,20	—	578	50°	179,35	—	157
30,0°	374,02	—	370	60°	107,97	—	108
32,5°	308,91	—	328	65°	85,70	—	98
35,0°	259,65	—	318	70°	79,24	—	97
37,5°	233,18	—	284	75°	73,35	—	96
40,0°	215,75	—	265	80°	70,40	—	88
42,5°	212,96	—	205	85°	72,21	—	68
45,0°	193,46	192,63	185	90°	68,40	67,97	65

Errore sistematico 2%

TABELLA IIb. -  $Energia = 0,776 - 0,800$  MeV.

Energia	0,776 [A7]	0,776 [A7]	0,800 [A3]	Energia	0,776 [A7]	0,776 [A7]	0,800 [A3]
$\vartheta$	$\sigma_{lab}(\vartheta)$ in mb/ster.			$\Theta$	$\sigma_{c.m.}(\Theta)$ in mb/ster.		
15,0°	—	—	4 955	30°	—	—	1 277
20,0°	1 476,73	1 644,14	1 510	40°	392,88	437,42	401
25,0°	593,80	—	594	50°	163,80	—	164
27,5°	471,85	—	363	55°	132,98	—	125
30,0°	401,06	—	342	60°	114,58	—	98
32,5°	352,44	—	317	65°	100,12	—	89
35,0°	306,11	—	309	70°	93,47	—	94
37,5°	284,76	—	296	75°	89,73	—	92
40,0°	280,12	—	282	80°	91,42	—	94
42,5°	266,02	—	267	85°	90,20	—	90
45,0°	263,51	259,97	242	90°	93,17	91,91	86
Errore sistematico 2%							

TABELLA IIc. -  $Energia = 0,85 - 9,90$  MeV.

Energia	0,854 [A6]	0,860 $\begin{smallmatrix} [A6] \\ [A5] \end{smallmatrix}$	0,867 [A7]	0,867 [A7]	0,900 [A3]
$\vartheta$	$\sigma_{lab}(\vartheta)$ in mb/ster.				
15,0°	4 373,32	4 235,73	—	—	3 127
20,0°	1 181,40	1 150,02	1 332,97	1 222,95	1 203
25,0°	550,20	540,97	561,36	566,00	589
27,5°	—	—	460,77	—	473
30,0°	399,66	400,71	420,58	417,19	406
32,5°	—	—	369,95	—	369
35,0°	352,58	357,10	368,41	360,48	420
37,5°	—	—	340,24	—	361
40,0°	336,65	336,70	325,02	321,24	348
42,5°	—	—	317,54	—	326
45,0°	304,21	309,37	308,86	304,44	276
$\Theta$	$\sigma_{c.m.}(\Theta)$ in mb/ster.				
30°	1 123,52	1 096,29	—	—	806
40°	341,06	305,96	354,63	327,37	320
50°	151,22	149,72	154,85	156,12	159
55°	—	—	129,87	—	130
60°	115,47	115,77	116,21	120,43	114
65°	—	—	109,66	—	106
70°	107,49	108,10	102,23	110,16	125
75°	—	—	107,22	—	115
80°	109,86	110,23	106,07	104,83	110
85°	—	—	107,67	—	109
90°	107,55	106,55	109,20	107,64	97
Errore sist.	2,5%	2,5%	2%	2%	



TABELLA II*d*.  
Energia = 1,20 MeV  $\begin{smallmatrix} [A6] \\ [A5] \end{smallmatrix}$

$\vartheta$	$\sigma_{\text{lab}}(\vartheta)$ in mb/ster.	$\Theta$	$\sigma_{\text{c.m.}}(\Theta)$ in mb/ster.
15°	2162,45	30°	559,68
20°	795,26	40°	211,56
25°	544,63	50°	151,73
30°	500,50	60°	144,19
35°	484,76	70°	149,42
40°	459,32	80°	149,58
45°	421,14	90°	148,40

Errore sistematico 2,5%

TABELLA II*e*.  
Energia = 1,39 MeV  $\begin{smallmatrix} [A6] \\ [A5] \end{smallmatrix}$

$\vartheta$	$\sigma_{\text{lab}}(\vartheta)$ in mb/ster.	$\Theta$	$\sigma_{\text{c.m.}}(\Theta)$ in mb/ster.
15°	1685,56	30°	439,49
20°	708,77	40°	188,57
25°	558,91	50°	151,17
30°	534,98	60°	155,14
35°	503,07	70°	155,53
40°	485,93	80°	159,59
45°	451,41	90°	159,70

Errore sistematico 2,5%

TABELLA II*f*. - Energia = 1,812 - 1,858 MeV.

Energia	1,812 $\begin{smallmatrix} [A6] \end{smallmatrix}$	1,830 $\begin{smallmatrix} [A6] \\ [A5] \end{smallmatrix}$	1,840 $\begin{smallmatrix} [A6] \end{smallmatrix}$	1,848 $\begin{smallmatrix} [A6] \end{smallmatrix}$	1,855 $\begin{smallmatrix} [A44] \end{smallmatrix}$	1,858 $\begin{smallmatrix} [A44] \end{smallmatrix}$
$\vartheta$	$\sigma_{\text{lab}}(\vartheta)$ in mb/ster.					
7,0°	—	—	—	—	23 072,84 $\pm$ 62,10	23 060,84 $\pm$ 59,80
8,0°	—	—	—	—	13 009,80 $\pm$ 37,70	13 065,96 $\pm$ 40,60
10,0°	—	—	—	—	4 904,54 $\pm$ 10,29	5 014,66 $\pm$ 9,52
12,0°	—	—	—	—	2 311,80 $\pm$ 5,78	2 332,53 $\pm$ 6,29
15,0°	1 171,58	1 105,11	1 087,66	1 084,44	1 057,31 $\pm$ 2,17	1 055,56 $\pm$ 1,10
17,5°	—	—	—	—	750,50 $\pm$ 1,94	747,65 $\pm$ 1,12
20,0°	634,63	628,67	620,13	—	620,22 $\pm$ 1,24	619,08 $\pm$ 1,30
25,0°	572,25	567,49	571,78	—	561,38 $\pm$ 1,29	561,24 $\pm$ 0,95
30,0°	553,39	534,68	547,19	557,16	549,72 $\pm$ 1,16	548,53 $\pm$ 0,66
35,0°	540,73	530,41	527,14	—	538,28 $\pm$ 1,35	538,14 $\pm$ 1,18
40,0°	500,92	509,49	505,38	520,53	517,34 $\pm$ 1,24	519,75 $\pm$ 2,39
45,0°	478,80	473,99	473,99	—	479,20 $\pm$ 1,34	479,70 $\pm$ 1,44
$\Theta$	$\sigma_{\text{c.m.}}(\Theta)$ in mb/ster.					
14°	—	—	—	—	5 753,21 $\pm$ 15,50	5 767,21 $\pm$ 15,08
16°	—	—	—	—	3 252,45 $\pm$ 7,92	3 266,49 $\pm$ 10,23
20°	—	—	—	—	1 257,60 $\pm$ 2,73	1 260,17 $\pm$ 2,40
24°	—	—	—	—	592,77 $\pm$ 1,48	598,28 $\pm$ 1,73
30°	294,87	286,02	281,51	280,91	278,24 $\pm$ 0,58	277,78 $\pm$ 0,47
35°	—	—	—	—	197,50 $\pm$ 0,51	196,75 $\pm$ 0,30
40°	168,83	167,32	164,98	—	167,53 $\pm$ 0,33	167,32 $\pm$ 0,35
50°	157,58	156,40	157,87	—	155,94 $\pm$ 0,36	155,90 $\pm$ 0,27
60°	160,19	153,88	157,35	160,55	159,92 $\pm$ 0,34	159,58 $\pm$ 0,19
70°	165,03	161,86	163,51	—	164,20 $\pm$ 0,41	164,16 $\pm$ 0,36
80°	165,47	167,60	166,24	168,67	167,53 $\pm$ 0,40	167,37 $\pm$ 0,77
90°	165,10	164,00	164,00	—	167,93 $\pm$ 0,47	167,75 $\pm$ 0,50
Err. sist.	2,5%	2,5%	2,5%	2,5%	0,3%	0,3%

- $E=2,1$  MeV [Tab. IIIa]    X  $E=3,3$  MeV [Tab. IIId]  
 ▲  $E=2,4$  MeV [Tab. IIIb]    /  $E=3,5$  MeV [Tab. IIIe]  
 ■  $E=3,0$  MeV [Tab. IIIc]    ●  $E=4,0$  MeV [Tab. IIIf]  
    %  $E=5,0$  MeV [Tab. IIIg]

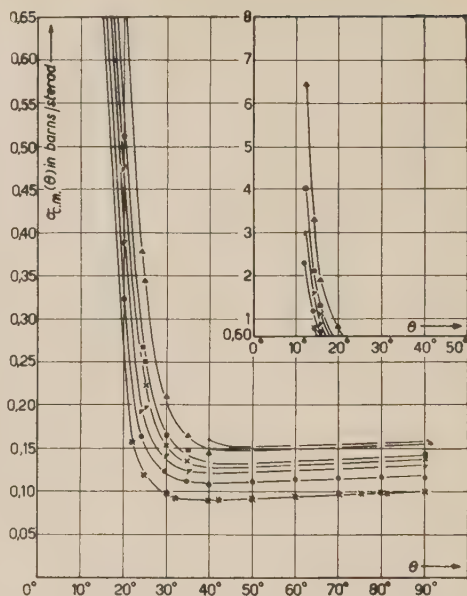
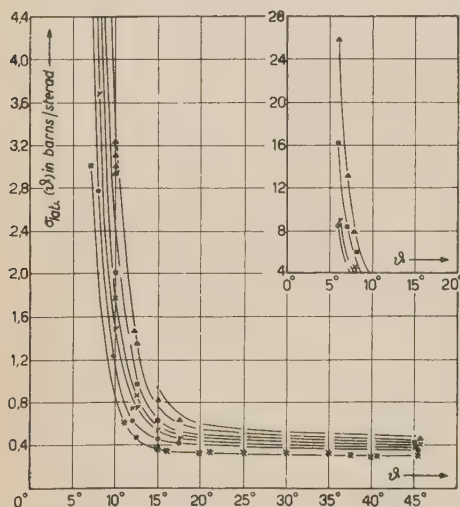


Grafico III. - Sezione d'urto differenziale protone-protone nel sistema del laboratorio  $\sigma_{\text{lab}}(\theta)$  e in quello del centro di massa  $\sigma_{\text{c.m.}}(\Theta)$ .

TABELLA IIIa. - Energia = 2,105 MeV  $\begin{smallmatrix} [A6] \\ [A5] \end{smallmatrix}$

$\theta$	$\sigma_{\text{lab}}(\theta)$ in mb/ster.	$\Theta$	$\sigma_{\text{c.m.}}(\Theta)$ in mb/ster.
15°	941,26	30°	246,84
20°	600,55	40°	159,77
25°	548,77	50°	151,92
30°	536,50	60°	154,23
35°	532,60	70°	152,46
40°	485,18	80°	157,05
45°	433,35	90°	154,02

Errore sistematico 2,5%



TABELLA IIIB. - *Energia* = 2,39 - 2,43 MeV.

Energia	2,393 <sup>[A6]</sup> <sub>[A5]</sub>	2,40 <sup>[A14]</sup>	2,42 <sup>[A16]</sup>	2,425 <sup>[A41]</sup>	2,43 <sup>[A17]</sup>
$\vartheta$	$\sigma_{\text{lab}}(\vartheta)$ in mb/ster.				
6,0°	—	—	—	25 661,16 $\pm$ 67,60	—
7,0°	—	—	—	13 349,68 $\pm$ 44,40	—
8,0°	—	8160	7 770 $\pm$ 100	7 596,68 $\pm$ 16,70	8 120
10,0°	—	3 230	3 050 $\pm$ 40	2 937,13 $\pm$ 8,41	3 090
12,0°	—	—	—	1 473,69 $\pm$ 2,25	—
12,5°	—	1 410	1 340 $\pm$ 20	—	1 350
15,0°	854,21	820	796 $\pm$ 8	777,21 $\pm$ 1,72	804
17,5°	—	635	628 $\pm$ 7	618,37 $\pm$ 1,74	631
20,0°	556,09	575	562 $\pm$ 4	552,11 $\pm$ 1,43	564
25,0°	529,75	540	528 $\pm$ 6	528,23 $\pm$ 1,22	528
30,0°	523,43	536	528 $\pm$ 10	526,31 $\pm$ 1,60	528
35,0°	503,48	522	503 $\pm$ 10	525,57 $\pm$ 1,58	503
40,0°	481,50	483	475 $\pm$ 8	485,15 $\pm$ 1,25	475
45,0°	439,09	459	443 $\pm$ 6	439,21 $\pm$ 1,06	443
$\Theta$	$\sigma_{\text{c.m.}}(\Theta)$ in mb/ster.				
12°	—	—	—	6 415,29 $\pm$ 17,20	—
14°	—	—	—	3 337,42 $\pm$ 11,20	—
16°	—	2 060	1 962 $\pm$ 25	1 899,17 $\pm$ 4,18	2 050
20°	—	820	774 $\pm$ 10	753,11 $\pm$ 2,18	785
24°	—	—	—	377,87 $\pm$ 0,55	—
25°	—	361	332 $\pm$ 5	—	343
30°	218,09	212	206 $\pm$ 2	204,53 $\pm$ 0,44	208
35°	—	166	165 $\pm$ 2	162,73 $\pm$ 0,45	165
40°	130,89	153	149 $\pm$ 1	149,22 $\pm$ 0,39	145
50°	146,80	149	146 $\pm$ 2	146,73 $\pm$ 0,35	146
60°	150,67	155	152 $\pm$ 3	150,38 $\pm$ 0,45	152
70°	153,60	159	153 $\pm$ 3	154,58 $\pm$ 0,50	153
60°	157,65	158	155 $\pm$ 3	156,50 $\pm$ 0,40	155
90°	156,65	163	158 $\pm$ 2	156,86 $\pm$ 0,32	158
Errore sist.	2,5%	2%	1,6%	0,3%	1,6%

TABELLA IIIc. - *Energia* = 3,00 - 3,05 MeV.

Energia	3,00 [A16]	3,037 [A44]	3,04 [A16]	3,05 [A17]
$\vartheta$	$\sigma_{\text{lab}}(\vartheta)$ in mb/ster.			
6,0°	—	16 187,92 $\pm$ 48,60	—	—
7,0°	—	8 420,04 $\pm$ 27,60	—	—
8,0°	5 220	4 844,04 $\pm$ 19,20	4 930 $\pm$ 70	5 030
10,0°	2 100	1 931,24 $\pm$ 5,79	1 990 $\pm$ 20	2 010
12,0°	—	1 040,52 $\pm$ 3,64	—	—
12,5°	1 000	—	963 $\pm$ 14	969
15,0°	657	618,87 $\pm$ 3,04	626 $\pm$ 8	631
17,5°	560	526,98 $\pm$ 1,54	537 $\pm$ 5	539
20,0°	512	486,92 $\pm$ 0,97	493 $\pm$ 5	494
25,0°	499	475,31 $\pm$ 1,19	483 $\pm$ 6	483
30,0°	484	476,00 $\pm$ 1,90	469 $\pm$ 9	469
35,0°	462	472,29 $\pm$ 1,89	450 $\pm$ 5	450
40,0°	441	433,50 $\pm$ 1,30	425 $\pm$ 8	425
45,0°	413	394,35 $\pm$ 1,09	402 $\pm$ 5	402
$\Theta$	$\sigma_{\text{c.m.}}(\Theta)$ in mb/ster.			
12°	—	4 046,98 $\pm$ 12,10	—	—
14°	—	2 105,01 $\pm$ 6,30	—	—
16°	1 318	1 211,01 $\pm$ 4,80	1 256 $\pm$ 18	1 270
20°	533	495,80 $\pm$ 1,80	506 $\pm$ 5	510
24°	—	266,80 $\pm$ 0,95	—	—
25°	256	—	247 $\pm$ 4	248
30°	170	162,86 $\pm$ 0,80	160 $\pm$ 2	163
35°	147	138,68 $\pm$ 0,40	141 $\pm$ 1	155
40°	136	131,60 $\pm$ 0,27	132 $\pm$ 1	131
50°	129	132,03 $\pm$ 0,36	133 $\pm$ 2	134
60°	140	136,00 $\pm$ 0,54	135 $\pm$ 3	135
70°	141	138,91 $\pm$ 0,55	137 $\pm$ 1	137
80°	144	139,84 $\pm$ 0,42	139 $\pm$ 3	139
90°	148	140,84 $\pm$ 0,39	142 $\pm$ 2	142
Errore sist.	2%	0,3%	1,6%	1,6%

TABELLA III d. - *Energia* = 3,26 - 3,44 MeV.

Energia	3,26 [A17]	3,27 [A16]	3,384 [A27]	3,435 [A27]
$\vartheta$	$\sigma_{\text{lab}}(\vartheta)$ in mb/ster.			
8,0°	4470	4390 $\pm$ 50	—	—
10,0°	1790	1770 $\pm$ 20	—	—
12,5°	869	864 $\pm$ 12	—	—
15,0°	605	600 $\pm$ 5	597,4 $\pm$ 10,9	550,2 $\pm$ 10,5
17,5°	513	512 $\pm$ 6	—	—
20,0°	479	478 $\pm$ 6	485,0 $\pm$ 9,2	462,2 $\pm$ 8,6
25,0°	473	473 $\pm$ 5	458,1 $\pm$ 8,4	451,0 $\pm$ 8,2
30,0°	450	450 $\pm$ 5	436,3 $\pm$ 8,5	442,8 $\pm$ 8,2
35,0°	441	441 $\pm$ 5	434,2 $\pm$ 8,1	418,9 $\pm$ 7,6
40,0°	410	410 $\pm$ 5	408,2 $\pm$ 7,6	403,2 $\pm$ 7,4
45,0°	380	380 $\pm$ 4	378,9 $\pm$ 7,0	377,4 $\pm$ 6,8
$\Theta$	$\sigma_{\text{c.m.}}(\Theta)$ in mb/ster.			
16°	1128	1108 $\pm$ 13	—	—
20°	505	449 $\pm$ 5	—	—
25°	223	221 $\pm$ 3	—	—
30°	157	155 $\pm$ 1	154,6 $\pm$ 2,8	142,9 $\pm$ 2,7
35°	138	134 $\pm$ 2	—	—
40°	133	127 $\pm$ 2	129,1 $\pm$ 2,5	123,0 $\pm$ 2,3
50°	131	131 $\pm$ 1	126,5 $\pm$ 2,3	124,5 $\pm$ 2,4
60°	130	130 $\pm$ 1	126,1 $\pm$ 2,5	128,0 $\pm$ 2,4
70°	134	134 $\pm$ 1	132,7 $\pm$ 2,2	128,0 $\pm$ 2,4
80°	134	134 $\pm$ 1	133,5 $\pm$ 2,6	131,9 $\pm$ 2,4
90°	134	134 $\pm$ 1	144,0 $\pm$ 2,5	133,0 $\pm$ 2,4
Errore sist.	1,6%	1,6%	—	—



TABELLA IIIe. - *Energia* = 3,500 - 3,527 MeV.

Energia	3,500 [A17]	3,520 [A16]	3,527 [A44]
$\vartheta$	$\sigma_{\text{lab}} (\vartheta)$ in mb/ster.		
6,0°	—	—	8 979,72 $\pm$ 32,60
7,0°	—	—	4 809,36 $\pm$ 21,12
8,0°	3 720	3 700 $\pm$ 60	3 628,00 $\pm$ 16,56
10,0°	1 550	1 530 $\pm$ 30	1 484,14 $\pm$ 4,24
12,0°	—	—	756,99 $\pm$ 3,56
12,5°	778	773 $\pm$ 02	—
15,0°	548	550 $\pm$ 8	535,42 $\pm$ 0,96
17,5°	474	473 $\pm$ 5	473,80 $\pm$ 1,24
20,0°	463	462 $\pm$ 5	446,07 $\pm$ 0,84
25,0°	442	442 $\pm$ 5	437,00 $\pm$ 0,88
30,0°	428	428 $\pm$ 4	450,94 $\pm$ 0,93
35,0°	418	418 $\pm$ 4	434,04 $\pm$ 1,14
40,0°	397	397 $\pm$ 4	397,50 $\pm$ 0,96
45,0°	366	366 $\pm$ 4	361,93 $\pm$ 1,04
$\Theta$	$\sigma_{\text{c.m.}} (\Theta)$ in mb/ster.		
12°	—	—	2 993,18 $\pm$ 8,40
14°	—	—	1 577,34 $\pm$ 5,28
16°	939	934 $\pm$ 15	907,00 $\pm$ 4,14
20°	397	392 $\pm$ 8	380,55 $\pm$ 1,06
24°	—	—	194,10 $\pm$ 0,89
25°	199	198 $\pm$ 3	—
30°	142	140 $\pm$ 2	140,90 $\pm$ 0,29
35°	124	123 $\pm$ 1	124,42 $\pm$ 0,31
40°	123	122 $\pm$ 1	120,56 $\pm$ 0,24
50°	121	121 $\pm$ 1	121,39 $\pm$ 0,25
60°	123	123 $\pm$ 1	125,26 $\pm$ 0,31
70°	127	127 $\pm$ 1	127,66 $\pm$ 0,38
80°	129	129 $\pm$ 1	129,05 $\pm$ 0,32
90°	130	130 $\pm$ 1	129,26 $\pm$ 0,36
Errore sistem.	1,6%	1,6%	0,3%

TABELLA III f. - *Energia* = 3,899 - 4,203 MeV.

Energia	3,899 <sup>[A44]</sup>	4,203 <sup>[A44] [A13]</sup>
$\vartheta$	$\sigma_{\text{lab}}(\vartheta)$ in mb/ster.	
6,0°	8 784,40 $\pm$ 47,00	8 439,32 $\pm$ 39,20
7,0°	5 146,40 $\pm$ 31,20	4 431,00 $\pm$ 35,10
8,0°	2 985,96 $\pm$ 10,20	2 573,44 $\pm$ 27,00
10,0°	1 254,22 $\pm$ 4,44	—
12,0°	666,70 $\pm$ 3,65	601,18 $\pm$ 2,52
15,0°	485,18 $\pm$ 2,89	451,52 $\pm$ 1,38
17,5°	436,20 $\pm$ 1,50	411,35 $\pm$ 1,95
20,0°	416,32 $\pm$ 0,65	394,12 $\pm$ 1,30
25,0°	419,64 $\pm$ 1,10	389,34 $\pm$ 1,13
30,0°	403,20 $\pm$ 1,50	388,64 $\pm$ 1,24
35,0°	405,01 $\pm$ 1,29	384,74 $\pm$ 1,15
40,0°	373,70 $\pm$ 0,93	353,46 $\pm$ 1,03
45,0°	337,74 $\pm$ 0,90	319,76 $\pm$ 0,99
$\Theta$	$\sigma_{\text{c.m.}}(\Theta)$ in mb/ster.	
12°	2 446,10 $\pm$ 11,75	2 109,83 $\pm$ 9,80
14°	1 286,60 $\pm$ 7,80	11 07,75 $\pm$ 9,02
16°	746,49 $\pm$ 2,55	643,36 $\pm$ 7,10
20°	321,62 $\pm$ 1,12	—
24°	170,95 $\pm$ 0,95	154,15 $\pm$ 0,68
30°	127,69 $\pm$ 0,84	118,82 $\pm$ 0,38
35°	114,79 $\pm$ 0,40	108,25 $\pm$ 0,39
40°	112,52 $\pm$ 0,21	106,52 $\pm$ 0,37
50°	113,79 $\pm$ 0,36	108,15 $\pm$ 0,32
60°	117,20 $\pm$ 0,50	111,04 $\pm$ 0,36
70°	119,12 $\pm$ 0,43	113,16 $\pm$ 0,38
80°	120,55 $\pm$ 0,32	114,02 $\pm$ 0,34
90°	120,62 $\pm$ 0,30	114,20 $\pm$ 0,33
Errore sistematico	0,3%	0,3%

TABELLA IIIg. - *Energia* = 5,00 - 5,14 MeV.

Energia	$\sigma_{\text{lab}} (\theta)$ in mb/ster.			
$\theta$	5 [A20]	5,07 [A28]	5,11 [A18]	5,14 [A39]
7,0°	—	3 025,3 $\pm$ 45,6	—	—
11,0°	—	612,5 $\pm$ 9,2	—	—
12,5°	473,7	—	—	—
15,0°	376,7	377,1 $\pm$ 4,9	—	—
16,0°	—	356,8 $\pm$ 6,0	—	—
20,0°	346,6	335,3 $\pm$ 8,4	—	—
21,0°	—	340,2 $\pm$ 6,1	—	—
25,0°	336,8 $\pm$ 7,3	333,9 $\pm$ 3,7	—	360,6 $\pm$ 8,0
30,0°	333,3 $\pm$ 7,3	328,7 $\pm$ 4,1	346,1	331,5 $\pm$ 9,4
35,0°	323,8 $\pm$ 7,0	313,6 $\pm$ 3,3	351,7	314,2 $\pm$ 7,8
37,5°	315,4	—	—	—
40,0°	304,3 $\pm$ 5,7	293,6 $\pm$ 3,2	312,5	288,9 $\pm$ 5,7
40,5°	302,0	—	—	—
45,0°	281,7 $\pm$ 5,0	280,0 $\pm$ 4,8	302,4	268,0 $\pm$ 4,8
$\Theta$	$\sigma_{\text{c.m.}} (\Theta)$ in mb/ster.			
14,0°	—	762,0 $\pm$ 11,1	—	—
22,0°	—	156,0 $\pm$ 2 ,6	—	—
25,0°	121,3	—	—	—
30,0°	97,5	97,6 $\pm$ 1,2	—	—
32,0°	—	92,8 $\pm$ 1,5	—	—
40,0°	92,2	89,2 $\pm$ 2,1	—	—
42,0°	—	91,1 $\pm$ 1,7	—	—
50,0°	92,9 $\pm$ 1,8	92,1 $\pm$ 1,1	—	99,9 $\pm$ 2,0
60,0°	96,2 $\pm$ 1,8	94,9 $\pm$ 1,2	100,0	94,7 $\pm$ 2,7
70,0°	98,8 $\pm$ 1,9	95,7 $\pm$ 1,0	103,0	94,6 $\pm$ 2,3
75,0°	99,4	—	—	—
80,0°	99,3 $\pm$ 1,9	95,8 $\pm$ 1,1	106,5	95,0 $\pm$ 1,9
81,0°	99,3	—	—	—
90,0°	99,6 $\pm$ 1,9	99,0 $\pm$ 2,0	108,0	94,8 $\pm$ 1,7
Errore sist.	1,20%	1,20%	2,5%	1,6%



- $E=5,8$  MeV [Tab. IVa]    ●  $E=9,8$  MeV [Tab. IVe]  
 ▲  $E=6,8$  MeV [Tab. IVb]    √  $E=10,0$  MeV [Tab. IVf]  
 ■  $E=7,3$  MeV [Tab. IVc]    ○  $E=14,5$  MeV [Tab. IVg]  
 ×  $E=8,0$  MeV [Tab. IVd]    ✱  $E=18,3$  MeV [Tab. IVh]  
 //  $E=31,0$  MeV [Tab. IVi]

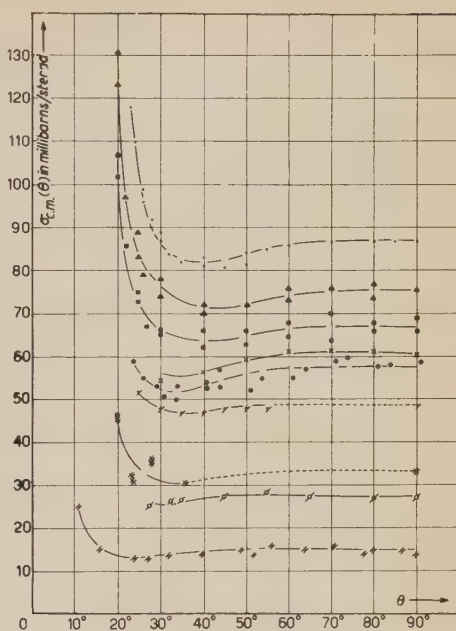
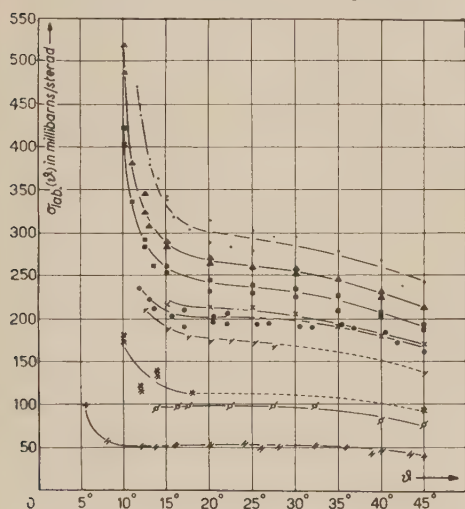


Grafico IV. — Sezione d'urto differenziale protone-protone nel sistema del laboratorio  $\sigma_{\text{lab}}(\theta)$  e in quello del centro di massa  $\sigma_{\text{c.m.}}(\theta)$ .

TABELLA IVa. — Energia = 5,77 – 5,86 MeV.

Energia	5,77 [A41]	5,86 [A30]	Energia	5,77 [A41]	5,86 [A30]
$\theta$	$\sigma_{\text{lab}}(\theta)$ in mb/ster.		$\Theta$	$\sigma_{\text{c.m.}}(\Theta)$ in mb/ster.	
11,500°	469,6 ± 3,1	—	23,00°	118,0 ± 0,9	—
11,935°	436,5 ± 3,5	—	23,87°	110,0 ± 0,8	—
13,000°	470,0 ± 2,5	387,4 ± 3,9	26,00°	95,91 ± 0,70	99,4 ± 1,0
13,925°	457,7 ± 2,4	—	27,85°	91,73 ± 0,79	—
15,000°	339,0 ± 2,0	342,7 ± 3,4	30,00°	87,30 ± 0,64	89,3 ± 0,9
15,920°	309,8 ± 2,3	—	31,84°	83,53 ± 0,73	—
17,500°	286,8 ± 2,0	—	35,00°	81,98 ± 0,58	—
20,000°	290,0 ± 2,4	315,4 ± 3,1	40,00°	82,82 ± 0,60	83,9 ± 0,8
22,500°	283,5 ± 2,3	—	45,00°	81,12 ± 0,67	—
25,000°	299,8 ± 2,2	303,8 ± 3,0	50,00°	83,28 ± 0,64	83,8 ± 0,8
27,380°	298,0 ± 2,3	—	54,76°	85,00 ± 0,63	—
30,000°	296,5 ± 2,3	299,7 ± 3,0	60,00°	85,70 ± 0,65	86,5 ± 0,9
34,850°	286,6 ± 2,2	—	69,70°	86,86 ± 0,70	—
35,000°	—	279,4 ± 3,0	70,00°	—	87,3 ± 0,9
39,840°	268,5 ± 2,1	—	79,68°	86,73 ± 0,70	—
40,000°	—	269,2 ± 2,8	80,00°	—	87,7 ± 0,9
42,365°	250,8 ± 2,0	—	84,73°	86,51 ± 0,65	—
44,840°	246,7 ± 2,0	—	89,68°	87,18 ± 0,70	—
45,000°	—	246,9 ± 2,5	90,00°	—	87,3 ± 0,9

Errore sistematico incluso in quello casuale

TABELLA IVb.

*Energia* = 6,846 MeV.

Energia	6,846 [A27]	6,846 [A27]
$\vartheta$	$\sigma_{\text{lab}}(\vartheta)$ in mb/ster.	
10,0°	517,6 $\pm$ 10,0	485,8 $\pm$ 10,4
11,0°	—	381,2 $\pm$ 8,2
12,5°	346,4 $\pm$ 6,8	324,3 $\pm$ 6,7
13,0°	—	308,2 $\pm$ 6,3
15,0°	290,3 $\pm$ 5,5	284,4 $\pm$ 5,6
20,0°	264,8 $\pm$ 5,1	270,0 $\pm$ 5,3
25,0°	260,6 $\pm$ 4,9	260,6 $\pm$ 5,0
30,0°	252,9 $\pm$ 4,8	258,4 $\pm$ 5,2
35,0°	248,1 $\pm$ 4,8	247,4 $\pm$ 4,8
40,0°	226,7 $\pm$ 4,4	232,3 $\pm$ 4,5
45,0°	212,3 $\pm$ 4,0	213,5 $\pm$ 4,1
$\Theta$	$\sigma_{\text{c.m.}}(\Theta)$ in mb/ster.	
20°	131,4 $\pm$ 2,5	123,3 $\pm$ 2,6
22°	—	97,1 $\pm$ 2,1
25°	88,7 $\pm$ 1,7	82,9 $\pm$ 1,7
26°	—	79,1 $\pm$ 1,6
30°	77,7 $\pm$ 1,4	73,6 $\pm$ 1,5
40°	70,5 $\pm$ 1,4	71,9 $\pm$ 1,4
50°	71,9 $\pm$ 1,6	71,9 $\pm$ 1,4
60°	73,1 $\pm$ 1,4	75,5 $\pm$ 1,4
70°	75,8 $\pm$ 1,5	75,6 $\pm$ 1,5
80°	74,2 $\pm$ 1,4	77,5 $\pm$ 1,9
90°	75,3 $\pm$ 1,4	76,3 $\pm$ 1,4

TABELLA IVc.

*Energia* = 7,03 - 7,50 MeV.

Energia	7,03 [A15]	7,50 [A27]
$\vartheta$	$\sigma_{\text{lab}}(\vartheta)$ in mb/ster.	
10,0°	402,8 $\pm$ 1,0	421,5 $\pm$ 8,6
11,0°	—	337,5 $\pm$ 6,3
12,5°	292,1 $\pm$ 0,7	283,8 $\pm$ 5,3
13,5°	—	260,8 $\pm$ 5,2
15,0°	260,6 $\pm$ 0,6	253,5 $\pm$ 4,8
20,0°	232,1 $\pm$ 0,6	246,6 $\pm$ 4,8
25,0°	229,8 $\pm$ 0,6	239,6 $\pm$ 4,4
30,0°	225,6 $\pm$ 0,6	237,1 $\pm$ 4,6
35,0°	210,2 $\pm$ 0,5	228,1 $\pm$ 4,4
40,0°	203,8 $\pm$ 0,5	209,2 $\pm$ 4,0
45,0°	188,1 $\pm$ 0,5	194,8 $\pm$ 3,7
$\Theta$	$\sigma_{\text{c.m.}}(\Theta)$ in mb/ster.	
20,0°	102,4 $\pm$ 0,3	106,7 $\pm$ 2,2
22,0°	—	85,9 $\pm$ 1,5
25,0°	74,8 $\pm$ 0,2	72,7 $\pm$ 1,3
27,0°	—	67,1 $\pm$ 1,3
30,0°	65,6 $\pm$ 0,2	66,6 $\pm$ 1,2
40,0°	61,7 $\pm$ 0,1	65,6 $\pm$ 1,3
50,0°	63,4 $\pm$ 0,2	66,1 $\pm$ 1,3
60,0°	65,1 $\pm$ 0,2	68,5 $\pm$ 1,3
70,0°	64,3 $\pm$ 0,2	69,7 $\pm$ 1,4
80,0°	66,4 $\pm$ 0,2	68,4 $\pm$ 1,4
90,0°	66,1 $\pm$ 0,2	69,2 $\pm$ 1,3

TABELLA IVd. - *Energia* = 8 MeV [A<sup>9</sup>]

$\vartheta$	$\sigma_{\text{lab}} (\vartheta)$ in mb/ster.	$\Theta$	$\sigma_{\text{c.m.}} (\Theta)$ in mb/ster.
15°	216 $\pm$ 4	30°	54,0 $\pm$ 1,1
20°	213 $\pm$ 4	40°	56,4 $\pm$ 1,1
25°	212 $\pm$ 4	50°	58,8 $\pm$ 1,2
30°	204 $\pm$ 4	60°	60,8 $\pm$ 1,2
35°	192 $\pm$ 4	70°	61,0 $\pm$ 1,2
40°	180 $\pm$ 4	80°	60,6 $\pm$ 1,2
45°	170 $\pm$ 3	90°	60,0 $\pm$ 1,2

TABELLA IVe. (\*) - *Energia* = 9,70 - 9,85 MeV.

Energia	9,70 [A40]	9,85 [A40]	Energia	9,70 [A40]	9,85 [A40]
$\vartheta$	$\sigma_{\text{lab}} (\vartheta)$ in mb/ster.		$\Theta$	$\sigma_{\text{c.m.}} (\Theta)$ in mb/ster.	
12,0°	—	236 $\pm$ 10	24°	—	59,2 $\pm$ 2,6
13,0°	—	222 $\pm$ 10	26°	—	55,3 $\pm$ 2,6
14,5°	207 $\pm$ 9	211 $\pm$ 9	29°	51,7 $\pm$ 2,3	53,6 $\pm$ 2,5
15,5°	—	203 $\pm$ 9	31°	—	50,9 $\pm$ 2,3
17,0°	211 $\pm$ 8	194 $\pm$ 8	34°	52,8 $\pm$ 2,1	49,6 $\pm$ 2,3
20,5°	199 $\pm$ 8	202 $\pm$ 8	41°	54,3 $\pm$ 2,6	54,8 $\pm$ 2,5
22,0°	194 $\pm$ 7	206 $\pm$ 7	44°	52,8 $\pm$ 2,6	56,8 $\pm$ 2,9
25,5°	195 $\pm$ 7	—	51°	54,3 $\pm$ 2,3	—
27,0°	196 $\pm$ 7	—	54°	55,4 $\pm$ 2,3	—
30,5°	194 $\pm$ 7	193 $\pm$ 7	61°	55,4 $\pm$ 2,3	54,1 $\pm$ 2,5
32,0°	193 $\pm$ 6	—	64°	56,7 $\pm$ 2,3	—
35,5°	194 $\pm$ 6	—	71°	58,8 $\pm$ 2,4	—
37,0°	192 $\pm$ 6	—	74°	59,9 $\pm$ 2,9	—
40,5°	186 $\pm$ 5	—	81°	58,2 $\pm$ 2,4	—
42,0°	173 $\pm$ 5	—	84°	57,8 $\pm$ 2,3	—
45,5°	164 $\pm$ 5	—	91°	58,5 $\pm$ 2,3	—

(\*) Cfr. Appendice.



TABELLA IVf. - *Energia* = 10,0 - 12,4 MeV.

Energia	10,0 [A10]	12,4 [A24]	Energia	10,0 [A10]	12,4 [A24]
$\vartheta$	$\sigma_{\text{lab}} (\vartheta)$ in mb/ster.		$\Theta$	$\sigma_{\text{c.m.}} (\Theta)$ in mb/ster.	
12,5°	211	—	25,0°	53,9	—
15,5°	189	—	30,0°	47,9	—
17,5°	180	—	35,0°	46,8	—
20,0°	174	—	40,0°	46,6	—
22,5°	175	—	45,0°	47,7	—
25,0°	173	—	50,0°	48,2	—
27,5°	169	—	55,0°	47,7	—
44,8°	—	120	85,6°	—	40,1
45,0°	139	—	90,0°	49,0	—

TABELLA IVg. - *Energia* = 14,5 MeV.

Energia	14,5 [A11]	14,5 [A12]	Energia	14,5 [A11]	14,5 [A12]
$\vartheta$	$\sigma_{\text{lab}} (\vartheta)$ in mb/ster.		$\Theta$	$\sigma_{\text{c.m.}} (\Theta)$ in mb/ster.	
10°	172 ± 1,2	180 ± 1,2	20°	44 ± 0,3	46 ± 0,3
12°	116 ± 0,8	120 ± 0,8	24°	30 ± 0,2	31 ± 0,2
14°	134 ± 1,5	138 ± 1,5	29°	35 ± 0,4	36 ± 0,4
18°	114 ± 1,0	114 ± 1,0	36°	30 ± 0,3	30 ± 0,3
45°	94 ± 0,6	94 ± 0,6	80°	33,4 ± 0,2	33,4 ± 0,2

TABELLA IVh. (\*) - *Energia* = 18,3 - 25,5 MeV.

Energia	18,3 [A42]	18,8 [A25]	21,9 [A25]	25,2 [A25]	25,45 [A25]
$\vartheta$	$\sigma_{\text{lab}} (\vartheta)$ in mb/ster.				
13,75°	95,5	—	—	—	—
16,25°	97,9	—	—	—	—
17,50°	99,2	—	—	—	—
22,50°	99,3	—	—	—	—
27,50°	98,0	—	—	—	—
32,50°	89,7	—	—	—	—
40,00°	81,0	—	—	—	—
45,00°	76,0	76,2	63,8	52,4	51,5
$\Theta$	$\sigma_{\text{c.m.}} (\Theta)$ in mb/ster.				
27,5°	24,5	—	—	—	—
32,5°	25,5	—	—	—	—
35,0°	26,0	—	—	—	—
45,0°	27,5	—	—	—	—
55,0°	28,0	—	—	—	—
65,0°	27,5	—	—	—	—
80,0°	27,0	—	—	—	—
90,0°	27,0	27,2	22,8	18,7	18,4

(\*) Cfr. Appendice.

TABELLA IVi. - *Energia* = 30,0 - 31,8 MeV.

Energia	30,0 [A35]	30,1 [A21]	31,45 [A42]	31,8 [A22]	31,8 [A22]	31,8 [A25]
$\vartheta$	$\sigma_{\text{lab}}(\vartheta)$ in mb/ster.					
5,5°	100,42 $\pm$ 8,72	—	—	—	—	—
8,0°	57,59 $\pm$ 2,30	—	—	—	—	—
12,0°	50,20 $\pm$ 1,49	51,76 $\pm$ 1,41	—	—	—	—
13,5°	—	—	51,04 $\pm$ 0,62	—	—	—
16,0°	53,28 $\pm$ 1,31	55,91 $\pm$ 1,34	—	—	—	—
20,0°	55,03 $\pm$ 1,24	56,98 $\pm$ 1,20	49,92 $\pm$ 0,56	—	—	—
24,0°	52,43 $\pm$ 1,13	57,15 $\pm$ 1,13	—	—	—	—
26,0°	—	—	50,30 $\pm$ 0,61	—	—	—
28,0°	45,75 $\pm$ 1,24	58,98 $\pm$ 1,02	—	—	—	—
32,0°	49,25 $\pm$ 1,12	55,30 $\pm$ 1,70	47,48 $\pm$ 0,68	—	—	—
36,0°	50,48 $\pm$ 1,07	53,30 $\pm$ 1,78	—	—	—	—
39,0°	—	—	43,80 $\pm$ 0,48	45,11 $\pm$ 0,50	—	—
40,0°	47,16 $\pm$ 0,98	50,19 $\pm$ 0,83	—	—	—	—
43,5°	43,38 $\pm$ 1,04	46,05 $\pm$ 0,91	—	—	—	—
45,0°	—	—	40,55 $\pm$ 0,45	40,56 $\pm$ 0,73	40,56 $\pm$ 0,73	43,56 $\pm$ 0,73
$\Theta$	$\sigma_{\text{c.m.}}(\Theta)$ in mb/ster.					
11°	25,22 $\pm$ 2,19	—	—	—	—	—
16°	14,54 $\pm$ 0,58	—	—	—	—	—
24°	12,82 $\pm$ 0,38	13,23 $\pm$ 0,36	—	—	—	—
27°	—	—	13,13 $\pm$ 0,16	—	—	—
32°	13,08 $\pm$ 0,34	14,02 $\pm$ 0,35	—	—	—	—
40°	14,64 $\pm$ 0,33	15,16 $\pm$ 0,32	13,27 $\pm$ 0,15	—	—	—
48°	15,17 $\pm$ 0,31	15,64 $\pm$ 0,31	—	—	—	—
52°	—	—	14,02 $\pm$ 0,17	—	—	—
56°	14,85 $\pm$ 0,35	16,70 $\pm$ 0,29	—	—	—	—
64°	14,52 $\pm$ 0,33	16,30 $\pm$ 0,28	14,05 $\pm$ 0,20	—	—	—
72°	15,60 $\pm$ 0,33	16,47 $\pm$ 0,27	—	—	—	—
78°	—	—	14,05 $\pm$ 0,15	14,15 $\pm$ 0,16	—	—
80°	15,39 $\pm$ 0,32	16,38 $\pm$ 0,27	—	—	—	—
87°	14,95 $\pm$ 0,36	16,00 $\pm$ 0,31	—	—	—	—
90°	—	—	14,30 $\pm$ 0,16	14,21 $\pm$ 0,26	14,34 $\pm$ 0,26	14,50 $\pm$ 0,26
Errore sistem.	3%	3%	0,5%	0,5%	0,5%	0,5%



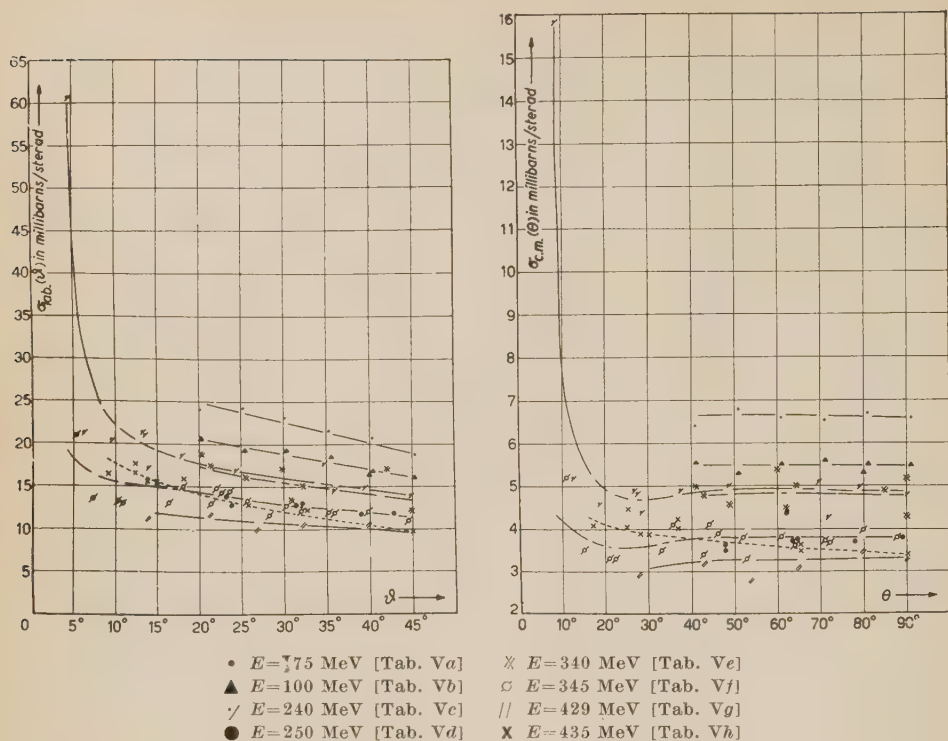


Grafico V. - Sezione d'urto differenziale protone-protone nel sistema del laboratorio  $\sigma_{lab}(\theta)$  e in quello del centro di massa  $\sigma_{c.m.}(\theta)$ .

TABELLA Va. (\*) - Energia = 75 - 95 MeV.

Energia	75 [A32]	95 [A51]	Energia	75 [A32]	95 [A51]
$\theta$	$\sigma_{lab}(\theta)$ in mb/ster.		$\Theta$	$\sigma_{c.m.}(\Theta)$ in mb/ster.	
20,5°	24,2	—	41°	6,4	—
25,5°	24,5	—	51°	6,8	—
30,5°	22,7	—	61°	6,6	—
35,5°	21,2	—	71°	6,55	—
40,5°	21,3	—	81°	7,0	—
45,5°	18,7	13,0	91°	6,6	4,6

(\*) Cfr. Appendice.

TABELLA Vb. - *Energia* = 100 - 164 MeV.

Ener.	100 <sup>[A32]</sup>	105 <sup>[A32]</sup>	118 <sup>[A34]</sup>	119 <sup>[A26]</sup>	120 <sup>[A34]</sup>	144 <sup>[A49]</sup>	163 <sup>[A34]</sup>	164 <sup>[A26]</sup>	164 <sup>[A34]</sup>
$\vartheta$	$\sigma_{\text{lab}}(\vartheta)$ in mb/ster.								
0,50°	20,1 ± 0,4	20,3	—	—	—	—	—	—	—
5,50°	19,8 ± 0,4	18,7	—	—	—	—	—	—	—
9,95°	—	—	—	—	—	—	—	—	13,6 ± 0,8
0,40°	—	—	—	—	—	—	13,2 ± 1,7	—	—
0,50°	19,3 ± 0,4	18,6	—	—	—	—	—	14,3 ± 1,4	—
1,50°	—	—	—	13,6 ± 1,4	13,7 ± 1,7	—	—	—	—
5,50°	18,5 ± 0,3	18,4	—	—	—	—	—	—	—
8,90°	—	—	—	—	13,2 ± 1,0	—	—	—	—
9,00°	—	—	—	10,0 ± 1,2	—	—	—	—	—
0,00°	—	16,4	—	—	—	—	—	—	—
0,50°	16,7 ± 0,3	—	—	—	—	—	—	—	—
2,60°	—	—	—	—	11,5 ± 0,7	—	11,0 ± 0,7	—	—
4,30°	—	—	—	—	—	—	—	—	10,1 ± 0,9
4,50°	—	—	—	11,2 ± 0,3	—	—	—	10,8 ± 0,8	—
4,60°	—	—	11,1 ± 0,3	—	—	—	—	—	—
5,00°	—	—	—	—	—	9,1 ± 0,3	—	—	10,2 ± 0,5
5,50°	15,8 ± 0,3	15,3	—	—	—	—	—	—	—
$\Theta$	$\sigma_{\text{c.m.}}(\Theta)$ in mb/ster.								
1,0°	5,6 ± 0,1	5,4	—	—	—	—	—	—	—
1,0°	5,5 ± 0,1	5,2	—	—	—	—	—	—	—
9,9°	—	—	—	—	—	—	—	—	3,88 ± 0,23
0,8°	—	—	—	—	—	—	4,08 ± 0,45	—	—
1,0°	5,6 ± 0,1	5,6	—	—	—	—	—	4,1 ± 0,4	—
3,0°	—	—	—	4,0 ± 0,4	4,03 ± 0,50	—	—	—	—
1,0°	5,7 ± 0,1	5,5	—	—	—	—	—	—	—
7,8°	—	—	—	—	4,25 ± 0,33	—	—	—	—
8,0°	—	—	—	4,2 ± 0,4	—	—	—	—	—
0,0°	—	5,3	—	—	—	—	—	—	—
1,0°	5,5 ± 0,1	—	—	—	—	—	—	—	—
5,2°	—	—	—	—	3,85 ± 0,25	—	3,88 ± 0,26	—	—
8,6°	—	—	—	—	—	—	—	—	3,54 ± 0,35
9,0°	—	—	—	3,95 ± 0,12	—	—	—	3,8 ± 0,3	—
9,2°	—	—	3,95 ± 0,12	—	—	—	—	—	—
0,0°	—	—	—	—	—	3,21 ± 0,11	—	—	3,60 ± 0,17
1,0°	5,6 ± 0,1	5,4	—	—	—	—	—	—	—

TABELLA Vc. (\*) - *Energia* = 240 MeV.

Energia	240 [A36] [A38]	240 [A37]
	$\sigma_{\text{lab}} (\vartheta)$ in mb/ster.	
$\vartheta$		
4,35°	63,2 $\pm$ 6,4	—
6,50°	20,4 $\pm$ 1,6	—
9,30°	18,1 $\pm$ 1,2	—
13,40°	—	18,9 $\pm$ 0,2
13,60°	17,0 $\pm$ 1,2	—
13,75°	—	18,8 $\pm$ 0,4
14,15°	17,3 $\pm$ 0,8	—
18,30°	17,6 $\pm$ 1,0	—
19,70°	—	19,1 $\pm$ 0,4
22,60°	17,8 $\pm$ 1,2	—
24,30°	—	17,4 $\pm$ 0,4
24,60°	—	17,3 $\pm$ 1,0
34,55°	—	16,6 $\pm$ 0,6
35,00°	—	17,3 $\pm$ 0,5
35,95°	13,9 $\pm$ 0,8	—
39,50°	—	15,0 $\pm$ 0,8
45,00°	—	13,6 $\pm$ 0,5
$\Theta$	$\sigma_{\text{c.m.}} (\Theta)$ in mb/ster.	
8,7°	15,80 $\pm$ 1,60	—
13,0°	5,16 $\pm$ 0,39	—
18,6°	4,59 $\pm$ 0,31	—
26,8°	—	4,85 $\pm$ 0,06
27,2°	4,38 $\pm$ 0,38	—
27,5°	—	4,83 $\pm$ 0,10
28,3°	4,43 $\pm$ 0,31	—
36,6°	4,90 $\pm$ 0,28	—
39,4°	—	5,03 $\pm$ 0,11
45,2°	4,81 $\pm$ 0,35	—
48,6°	—	4,96 $\pm$ 0,10
49,2°	—	4,82 $\pm$ 0,26
69,1°	—	5,02 $\pm$ 0,16
70,0°	—	5,25 $\pm$ 0,14
71,9°	4,33 $\pm$ 0,22	—
79,0°	—	5,05 $\pm$ 0,15
90,0°	—	4,81 $\pm$ 0,19

(\*) Cfr. Appendice.



TABELLA Vd. - *Energia* = 247 - 271 MeV.

Energia	247 [A34]	249 [A26]	249 [A34]	250 [A34]	271 [A49]
$\vartheta$	$\sigma_{\text{lab}} (\vartheta)$ in mb/ster.				
23,7°	—	—	—	13,0 $\pm$ 1,8	—
24,0°	—	12,6 $\pm$ 1,1	—	—	—
31,0°	14,9 $\pm$ 1,1	—	—	—	—
31,5°	—	12,6 $\pm$ 1,1	—	—	—
32,3°	—	—	—	13,0 $\pm$ 0,7	—
39,0°	—	11,1 $\pm$ 0,5	—	—	—
39,2°	—	—	—	10,8 $\pm$ 0,5	—
43,5°	—	10,9 $\pm$ 0,4	—	—	—
43,6°	—	—	—	11,0 $\pm$ 0,6	—
43,7°	—	—	10,4 $\pm$ 0,3	—	—
43,8°	—	—	—	10,7 $\pm$ 0,6	—
44,8°	9,75 $\pm$ 0,4	—	—	—	—
45,0°	—	—	—	—	10,4 $\pm$ 0,9
$\Theta$	$\sigma_{\text{c.m.}} (\Theta)$ in mb/ster.				
47,4°	—	—	—	3,60 $\pm$ 0,50	—
48,0°	—	3,5 $\pm$ 0,3	—	—	—
62,0°	4,38 $\pm$ 0,27	—	—	—	—
63,0°	—	3,7 $\pm$ 0,3	—	—	—
64,6°	—	—	—	3,84 $\pm$ 0,20	—
78,0°	—	3,69 $\pm$ 0,15	—	—	—
78,4°	—	—	—	3,61 $\pm$ 0,15	—
87,0°	—	3,64 $\pm$ 0,11	—	—	—
87,2°	—	—	—	3,67 $\pm$ 0,21	—
87,4°	—	—	3,69 $\pm$ 0,10	—	—
87,6°	—	—	—	3,77 $\pm$ 0,21	—
89,6°	3,42 $\pm$ 0,16	—	—	—	—
90,0°	—	—	—	—	3,67 $\pm$ 0,34

TABELLA Ve. (\*) - *Energia* = 340 MeV.

Energia	340[A19] [A23]	340[A19] [A23]	Energia	340[A19] [A23]	340[A19] [A23]
$\vartheta$	$\sigma_{\text{lab}} (\vartheta)$ in mb/ster.		$\Theta$	$\sigma_{\text{c.m.}} (\Theta)$ in mb/ster.	
20,5°	—	18,6 $\pm$ 3,6	41°	—	4,95 $\pm$ 0,6
21,5°	—	17,7 $\pm$ 3,5	43°	—	4,77 $\pm$ 0,9
24,5°	—	16,4 $\pm$ 3,5	49°	—	4,59 $\pm$ 0,9
30,0°	18,7 $\pm$ 1,4	—	60°	5,40 $\pm$ 0,4	—
31,0°	—	15,4 $\pm$ 1,4	62°	—	4,50 $\pm$ 0,4
32,0°	17,1 $\pm$ 2,0	—	64°	5,04 $\pm$ 0,6	—
42°,5	14,4 $\pm$ 1,8	—	85°	4,85 $\pm$ 0,6	—
45,0°	14,8 $\pm$ 1,5	12,2 $\pm$ 0,9	90°	5,22 $\pm$ 0,5	4,39 $\pm$ 0,3

(\*) Cfr. Appendice.

TABELLA Vf. - *Energia* = 345 MeV.

Energia	345 <sup>[A26]</sup> [A31]	345 <sup>[A26]</sup> [A31]	345 [A39]	345 [A39]
$\theta$	$\sigma_{\text{lab}}(\theta)$ in mb/ster.			
5,65°	20,8 ± 2,0	—	20,96 ± 1,6	—
7,50°	13,9 ± 0,6	—	—	—
7,60°	—	—	13,70 ± 0,76	—
10,50°	13,0 ± 1,2	—	—	—
10,55°	—	—	13,83 ± 0,39	—
10,85°	—	—	12,00 ± 0,58	—
11,25°	—	—	13,80 ± 0,36	—
16,50°	13,4 ± 0,6	—	—	—
16,55°	—	—	13,48 ± 0,42	—
17,80°	—	—	—	16,4 ± 0,8
18,00°	—	15,6 ± 1,0	—	—
18,20°	—	—	—	15,9 ± 0,6
21,40°	—	—	12,73 ± 0,37	—
21,50°	12,6 ± 0,7	—	—	—
21,70°	—	—	—	14,0 ± 0,5
22,00°	—	14,8 ± 1,1	—	15,4 ± 0,5
22,90°	—	—	—	13,4 ± 0,3
23,00°	—	14,0 ± 0,7	—	—
23,05°	—	—	—	14,7 ± 0,4
26,00°	—	13,7 ± 0,7	—	—
26,20°	—	—	—	13,6 ± 0,4
26,50°	12,4 ± 0,7	—	—	—
26,60°	—	—	12,46 ± 0,36	—
30,40°	—	—	—	13,3 ± 0,4
30,50°	—	13,1 ± 1,0	—	—
32,00°	—	12,2 ± 1,0	—	12,4 ± 0,5
35,30°	—	—	—	12,1 ± 0,5
35,50°	—	12,2 ± 0,5	—	—
36,10°	—	—	—	11,9 ± 0,4
40,00°	—	12,2 ± 1,0	—	—
40,10°	—	—	—	11,8 ± 0,4
43,80°	—	—	—	11,2 ± 0,3
44,00°	—	10,7 ± 0,6	—	—
44,10°	—	—	—	11,0 ± 0,2
44,30°	—	—	—	10,5 ± 0,2
44,60°	—	—	—	11,8 ± 1,0

segue TABELLA Vf.

Energia	345 [A26] [A31]	345 [A26] [A31]	345 [A39]	345 [A39]
$\Theta$	$\sigma_{c.m.} (\Theta)$ in mb/ster.			
11,3°	5,2 $\pm$ 0,5	—	5,24 $\pm$ 0,40	—
15,0°	3,5 $\pm$ 0,3	—	—	—
15,2°	—	—	3,46 $\pm$ 0,19	—
21,0°	3,3 $\pm$ 0,3	—	—	—
21,1°	—	—	3,51 $\pm$ 0,10	—
21,7°	—	—	3,06 $\pm$ 0,15	—
22,5°	—	—	3,52 $\pm$ 0,09	—
33,0°	3,5 $\pm$ 0,2	—	—	—
33,1°	—	—	3,51 $\pm$ 0,11	—
35,6°	—	—	—	4,31 $\pm$ 0,21
36,0°	—	4,1 $\pm$ 0,3	—	—
36,4°	—	—	—	3,93 $\pm$ 0,15
42,8°	—	—	3,44 $\pm$ 0,10	—
43,0°	3,4 $\pm$ 0,2	—	—	—
43,4°	—	—	—	3,97 $\pm$ 0,15
44,0°	—	4,0 $\pm$ 0,3	—	4,17 $\pm$ 0,13
45,8°	—	—	—	3,64 $\pm$ 0,09
46,0°	—	3,8 $\pm$ 0,2	—	—
46,1°	—	—	—	3,99 $\pm$ 0,11
52,0°	—	3,8 $\pm$ 0,2	—	—
52,4°	—	—	—	3,77 $\pm$ 0,10
53,0°	3,3 $\pm$ 0,2	—	—	—
53,2°	—	—	3,34 $\pm$ 0,10	—
60,8°	—	—	—	3,83 $\pm$ 0,13
61,0°	—	3,8 $\pm$ 0,3	—	—
64,0°	—	3,6 $\pm$ 0,3	—	3,64 $\pm$ 0,15
70,6°	—	—	—	3,67 $\pm$ 0,16
71,0°	—	3,7 $\pm$ 0,2	—	—
72,2°	—	—	—	3,67 $\pm$ 0,11
80,0°	—	4,0 $\pm$ 0,3	—	—
80,2°	—	—	—	3,95 $\pm$ 0,16
87,6°	—	—	—	3,86 $\pm$ 0,10
88,0°	—	3,7 $\pm$ 0,2	—	—
88,2°	—	—	—	3,80 $\pm$ 0,08
88,6°	—	—	—	3,70 $\pm$ 0,08
89,2°	—	—	—	4,15 $\pm$ 0,36



TABELLA Vg. - *Energia* = 429 MeV [A49]

$\vartheta$	$\sigma_{\text{lab}} (\vartheta)$ in mb/ster.	$\Theta$	$\sigma_{\text{c.m.}} (\Theta)$ in mb/ster.
14,0°	11,10 $\pm$ 0,78	28,0°	2,86 $\pm$ 0,20
21,5°	11,83 $\pm$ 0,78	43,0°	3,18 $\pm$ 0,21
27,0°	10,04 $\pm$ 0,71	54,0°	2,82 $\pm$ 0,20
32,6°	10,48 $\pm$ 0,64	65,2°	3,11 $\pm$ 0,19
40,0°	10,75 $\pm$ 0,74	80,0°	3,51 $\pm$ 0,23
45,0°	9,67 $\pm$ 0,37	90,0°	3,42 $\pm$ 0,12

TABELLA Vh. (\*) - *Energia* = 435 - 437 MeV.

<i>Energia</i>	435 [A43]	437 [A53] [A54]
$\vartheta$	$\sigma_{\text{lab}} (\vartheta)$ in mb/ster.	
8,30°	—	15,95 $\pm$ 0,95
12,60°	17,52 $\pm$ 1,00	16,38 $\pm$ 0,48
13,90°	—	15,74 $\pm$ 0,78
15,00°	—	15,33 $\pm$ 0,47
18,20°	15,80 $\pm$ 0,56	15,00 $\pm$ 0,46
25,25°	—	13,32 $\pm$ 0,43
32,65°	13,38 $\pm$ 0,40	12,22 $\pm$ 0,35
45,00°	9,49 $\pm$ 0,30	9,49 $\pm$ 0,30
$\Theta$	$\sigma_{\text{c.m.}} (\Theta)$ in mb/ster.	
16,6°	—	4,04 $\pm$ 0,24
25,2°	4,49 $\pm$ 0,25	4,20 $\pm$ 0,12
27,8°	—	3,97 $\pm$ 0,20
30,0°	—	3,93 $\pm$ 0,12
36,4°	4,16 $\pm$ 0,14	3,93 $\pm$ 0,12
50,5°	—	3,70 $\pm$ 0,12
65,3°	3,59 $\pm$ 0,10	3,49 $\pm$ 0,10
90,0°	3,39 $\pm$ 0,10	3,39 $\pm$ 0,10

(\*) Cfr. Appendice.

**Valori sperimentali**  
**della sezione d'urto differenziale neutrone-protone**

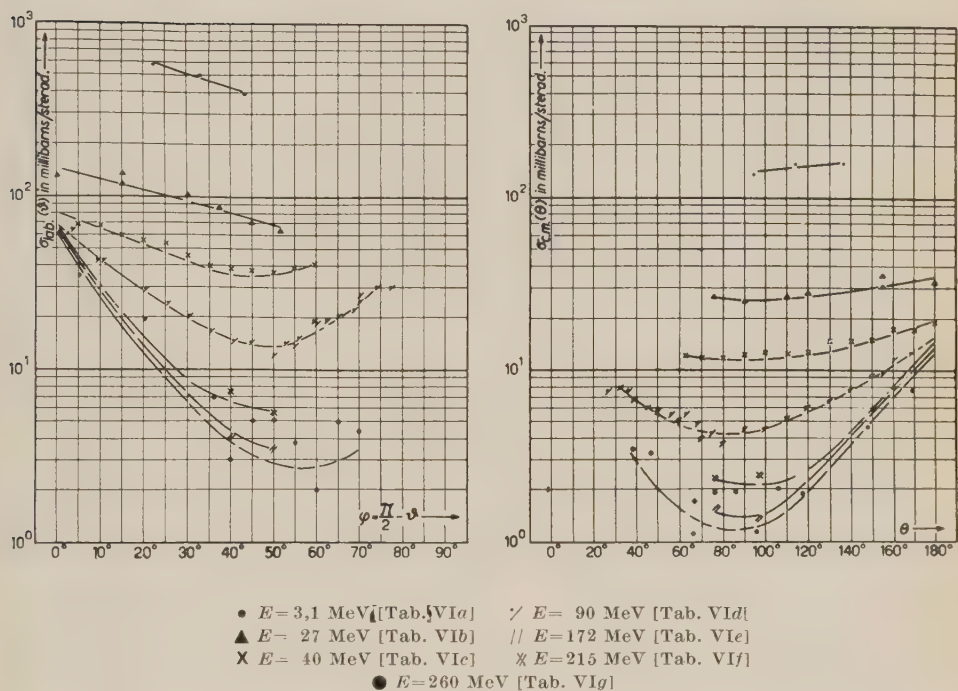


Grafico VI. - Sezione d'urto differenziale neutrone-protone nel sistema del laboratorio  $\sigma_{\text{lab}}(\theta)$  e in quello del centro di massa  $\sigma_{\text{c.m.}}(\Theta)$ .

TABELLA VIa. - Energia = 3,1 MeV [B58]

$\theta$	$\sigma_{\text{lab}}(\theta)$ in mb/ster.	$\Theta$	$\sigma_{\text{c.m.}}(\Theta)$ in mb/ster.
22°	$583 \pm 8,8$	136°	$157 \pm 2,2$
33°	$501 \pm 6,7$	114°	$155 \pm 2,0$
43°	$397 \pm 5,7$	94°	$136 \pm 1,9$

TABELLA VIb. (\*) -- *Energia* = 27 MeV [B62]

<i>Energia</i>	27 [B62]	27 [B62]	<i>Energia</i>	27 [B62]	27 [B62]
$\vartheta$	$\sigma_{\text{lab}}(\vartheta)$ in mb/ster.		$\Theta$	$C_{\text{c.m.}}(\Theta)$ in mb/ster.	
0,0°	129 $\pm$ 5	128,0 $\pm$ 5,0	180°	32,0 $\pm$ 1,3	32,3 $\pm$ 1,3
15,0°	136 $\pm$ 4	117,0 $\pm$ 5,0	155°	35,2 $\pm$ 1,0	30,0 $\pm$ 1,3
30,0°	101 $\pm$ 3	97,4 $\pm$ 4,0	120°	29,0 $\pm$ 1,0	27,8 $\pm$ 1,3
37,5°	---	85,0 $\pm$ 5,4	110°	—	27,0 $\pm$ 1,8
45,0°	69 $\pm$ 6	71,4 $\pm$ 3,0	90°	24,8 $\pm$ 2,0	25,5 $\pm$ 1,0
52,0°	—	62,0 $\pm$ 3,0	76°	—	27,8 $\pm$ 1,0

TABELLA VIc. — *Energia* = 40 MeV [B51]

$\vartheta$	$\sigma_{\text{lab}}(\vartheta)$ in mb/ster.	$\Theta$	$\sigma_{\text{c.m.}}(\Theta)$ in mb/ster.
0°	76,1 $\pm$ 2,8	180°	19,0 $\pm$ 0,7
5°	68,1 $\pm$ 2,2	170°	17,0 $\pm$ 0,5
10°	66,3 $\pm$ 2,2	160°	16,9 $\pm$ 0,6
15°	58,2 $\pm$ 2,2	150°	15,3 $\pm$ 0,6
20°	54,8 $\pm$ 2,2	140°	14,6 $\pm$ 0,6
25°	52,1 $\pm$ 2,2	130°	14,5 $\pm$ 0,6
30°	44,0 $\pm$ 2,2	120°	12,7 $\pm$ 0,6
35°	39,0 $\pm$ 2,2	110°	12,0 $\pm$ 0,6
40°	38,3 $\pm$ 2,2	100°	12,6 $\pm$ 0,6
45°	34,1 $\pm$ 2,2	90°	11,9 $\pm$ 0,7
50°	35,0 $\pm$ 2,2	80°	11,4 $\pm$ 0,7
55°	38,0 $\pm$ 2,2	70°	11,5 $\pm$ 0,8
59°	40,0 $\pm$ 2,2	62°	11,7 $\pm$ 0,8

(\*) Cfr. Appendice.



TABELLA VI<sup>d</sup>. (\*) - *Energia* = 90 MeV.

Energia	90 [B49] [B51]	90 [B60]	93 [B76]
$\vartheta$	$\sigma_{\text{lab}}(\vartheta)$ in mb/ster.		
0,0°	78,00 ± 1,00	—	—
1,2°	—	—	51,60 ± 1,32
2,0°	65,00 ± 1,00	—	—
2,3°	—	—	50,92 ± 1,24
3,0°	64,80 ± 0,88	—	—
4,2°	—	—	49,87 ± 1,20
5,0°	59,10 ± 0,87	—	—
6,1°	—	—	47,60 ± 1,16
9,1°	—	—	42,78 ± 1,08
10,5°	42,73 ± 0,86	—	—
12,0°	—	—	31,45 ± 0,86
15,5°	30,18 ± 0,84	—	—
20,5°	29,33 ± 0,83	—	—
24,5°	23,76 ± 0,79	—	—
30,5°	20,98 ± 0,76	—	—
35,5°	16,85 ± 0,71	—	—
40,5°	13,98 ± 0,67	—	—
44,5°	13,93 ± 0,62	—	—
50,0°	12,01 ± 0,68	—	—
53,0°	—	13,7 ± 0,6	—
55,0°	12,79 ± 0,72	—	—
56,0°	—	15,8 ± 0,7	—
59,0°	—	19,0 ± 0,8	—
60,0°	18,10 ± 0,76	—	—
62,0°	—	19,2 ± 0,8	—
65,0°	21,48 ± 0,80	21,6 ± 0,9	—
68,0°	—	22,6 ± 0,9	—
71,0°	—	25,0 ± 1,0	—
71,6°	27,74 ± 0,84	—	—
74,0°	—	30,4 ± 1,1	—
77,0°	—	29,6 ± 1,5	—

(\*) Cfr. Appendice.

segue TABELLA Vid.

Energia	90 [B49] [B51]	90 [B60]	93 [B76]
$\Theta$	$\sigma_{c.m.}(\Theta)$ in mb/ster.		
180,0°	$15,6 \pm 1,0$	—	—
177,5°	—	—	$12,90 \pm 0,33$
176,0°	$13,5 \pm 0,8$	—	—
175,4°	—	—	$12,73 \pm 0,31$
174,0°	$13,1 \pm 0,5$	—	—
171,5°	—	—	$12,50 \pm 0,30$
170,0°	$12,7 \pm 1,2$	—	—
167,5°	—	—	$11,96 \pm 0,29$
161,4°	—	—	$10,75 \pm 0,27$
159,0°	$10,9 \pm 2,0$	—	—
155,4°	—	—	$9,53 \pm 0,26$
149,0°	$9,2 \pm 0,8$	—	—
139,0°	$7,8 \pm 0,7$	—	—
129,0°	$6,6 \pm 0,9$	—	—
119,0°	$6,0 \pm 0,3$	—	—
109,0°	$5,2 \pm 0,3$	—	—
99,0°	$4,6 \pm 0,6$	—	—
89,0°	$4,7 \pm 0,6$	—	—
79,0°	$3,8 \pm 0,8$	—	—
74,0°	—	$4,28 \pm 0,19$	—
69,0°	$4,0 \pm 0,6$	—	—
68,0°	—	$4,80 \pm 0,20$	—
62,0°	—	$5,42 \pm 0,22$	—
59,0°	$5,1 \pm 0,6$	—	—
56,0°	—	$5,48 \pm 0,22$	—
49,0°	$5,7 \pm 1,2$	$6,01 \pm 0,24$	—
44,0°	—	$6,11 \pm 0,26$	—
38,0°	—	$6,77 \pm 0,29$	—
36,0°	$7,6 \pm 1,7$	—	—
32,0°	—	$8,00 \pm 0,34$	—
26,0°	—	$7,60 \pm 0,39$	—
Errore sistem.	—	0,7%	—

TABELLA VIe.

*Energia* = 172 MeV [B69]

$\vartheta$	$\sigma_{\text{lab}} (\vartheta)$ in mb/ster.
0,0°	72,1 $\pm$ 27,0
7,5°	47,4 $\pm$ 7,0
10,0°	33,0 $\pm$ 7,5
10,7°	30,4 $\pm$ 6,0
15,0°	22,1 $\pm$ 4,0
19,1°	14,0 $\pm$ 4,5
29,8°	7,5 $\pm$ 3,6
30,0°	8,9 $\pm$ 2,0
40,0°	7,5 $\pm$ 1,0
50,0°	5,7 $\pm$ 1,7
<hr/>	
$\Theta$	$\sigma_{\text{c.m.}} (\Theta)$ in mb/ster.
180,0°	16,6 $\pm$ 6,8
164,2°	10,9 $\pm$ 1,4
158,8°	7,6 $\pm$ 1,5
157,3°	7,0 $\pm$ 1,2
148,4°	5,3 $\pm$ 0,8
139,9°	3,5 $\pm$ 0,9
117,7°	2,1 $\pm$ 0,9
117,2°	2,5 $\pm$ 0,6
96,9°	2,4 $\pm$ 0,4
76,9°	2,3 $\pm$ 0,7

TABELLA VI f.

*Energia* = 215 MeV [B69]

$\vartheta$	$\sigma_{\text{lab}} (\vartheta)$ in mb/ster.
0,0°	60,8 $\pm$ 14,0
7,5°	38,6 $\pm$ 3,3
10,0°	32,9 $\pm$ 3,7
10,7°	30,3 $\pm$ 6,5
15,0°	23,4 $\pm$ 2,3
19,1°	17,4 $\pm$ 1,7
29,8°	9,3 $\pm$ 1,2
30,0°	8,0 $\pm$ 1,0
30,0°	4,1 $\pm$ 0,4
50,0°	3,6 $\pm$ 0,6
<hr/>	
$\Theta$	$\sigma_{\text{c.m.}} (\Theta)$ in mb/ster.
180,0°	13,40 $\pm$ 2,80
164,2°	8,89 $\pm$ 0,66
158,8°	7,58 $\pm$ 0,75
157,3°	6,97 $\pm$ 1,31
148,8°	5,38 $\pm$ 0,47
139,9°	4,18 $\pm$ 0,35
117,7°	2,53 $\pm$ 0,37
117,2°	2,40 $\pm$ 0,32
96,9°	1,31 $\pm$ 0,12
76,9°	1,45 $\pm$ 0,22

TABELLA VIg. - *Energia* = 260 MeV [B55]

$\vartheta$	$\sigma_{\text{lab}} (\vartheta)$ in mb/ster.	$\Theta$	$\sigma_{\text{c.m.}} (\Theta)$ in mb/ster.
0,00°	62,0 $\pm$ 9,0	180,0°	13,7 $\pm$ 2,1
5,35°	35,4 $\pm$ 3,8	169,3°	7,8 $\pm$ 0,8
10,75°	28,7 $\pm$ 1,5	158,7°	6,4 $\pm$ 0,3
15,95°	20,4 $\pm$ 1,9	148,1°	4,7 $\pm$ 0,4
21,20°	18,7 $\pm$ 1,3	137,6°	4,5 $\pm$ 0,3
26,45°	11,0 $\pm$ 1,6	127,1°	2,8 $\pm$ 0,4
31,65°	7,0 $\pm$ 0,9	116,7°	1,9 $\pm$ 0,24
36,75°	6,9 $\pm$ 0,7	106,5°	2,02 $\pm$ 0,21
40,00°	3,4 $\pm$ 0,8	96,3°	1,09 $\pm$ 0,26
45,00°	5,2 $\pm$ 0,4	86,3°	1,85 $\pm$ 0,14
50,00°	4,8 $\pm$ 1,7	76,4°	1,9 $\pm$ 0,7
55,00°	3,7 $\pm$ 0,9	66,6°	1,7 $\pm$ 0,4
60,00°	2,0 $\pm$ 1,2	60,8°	1,1 $\pm$ 0,6
65,00°	5,1 $\pm$ 1,0	47,2°	3,3 $\pm$ 0,6
70,00°	4,4 $\pm$ 0,9	37,7°	3,6 $\pm$ 0,7



Valori sperimentali della sezione d'urto totale neutrone-protone

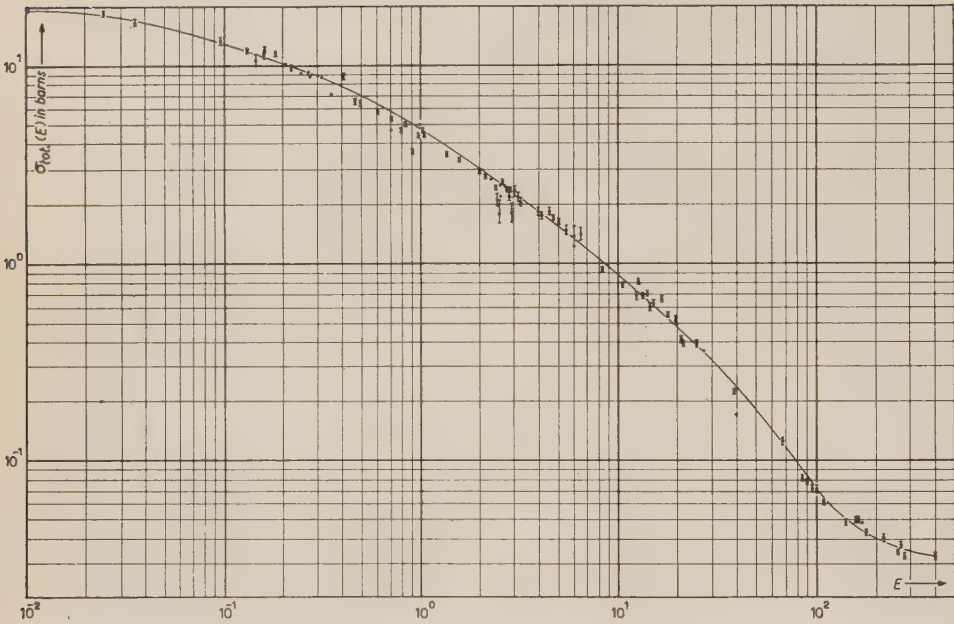


Grafico VII. -- ● Valori sperimentali della sezione d'urto totale neutrone-protone.

TABELLA VII (\*)

Energia	Bibliografia	$\sigma_{tot}$ in barn	Energia	Bibliografia	$\sigma_{tot}$ in barn
0,024	[B44]	$18,15 \pm 0,05$	0,270	[B44]	8,70
0,035	[B41] [B42]	$16,74 \pm 0,41$	0,320	[B44]	8,70
0,095	[B41] [B42]	$13,46 \pm 0,39$	0,350	[B40]	$7,15 \pm 0,24$
0,130	[B44]	$11,85 \pm 0,15$	0,400	[B24]	$8,70 \pm 0,90$
0,140	[B18]	$10,50 \pm 0,90$	0,460	[B40]	$6,52 \pm 0,15$
0,157	[B44]	11,10	0,490	[B41] [B42]	$6,33 \pm 0,21$
0,160	[B44]	$12,00 \pm 0,30$	0,600	[B44]	$5,85 \pm 0,25$
0,180	[B44]	$11,30 \pm 0,20$	0,700	[B 7]	4,70
0,200	[B44]	10,00	0,720	[B44]	$5,22 \pm 0,12$
0,220	[B44]	$9,60 \pm 0,40$	0,798	[B53]	$4,70 \pm 0,04$
0,245	[B44]	9,20	0,830	[B44]	$5,00 \pm 0,10$
0,265	[B41]	$9,12 \pm 0,24$	0,900	[B25] [B27]	$3,70 \pm 0,35$

(\*) Cfr. Appendice.

segue TABELLA VII.

Energia	Bibliografia	$\sigma_{\text{tot}}$ in barn	Energia	Bibliografia	$\sigma_{\text{tot}}$ in barn
0,900	[B29]	$5,50 \pm 1,10$	13,50	[B43]	$0,694 \pm 0,019$
0,970	[B40]	$4,45 \pm 0,08$	14,00	[B23]	$0,70 \pm 0,06$
1,000	[B40]	$4,16 \pm 0,15$	14,00	[B61]	$0,77 \pm 0,04$
1,078	[B53]	$4,46 \pm 0,03$	14,00	[B66] [B67]	$0,689 \pm 0,005$
1,340	[B53]	$3,64 \pm 0,04$	14,00	[B70]	$0,69 \pm 0,06$
1,578	[B53]	$3,33 \pm 0,02$	14,00	[B71]	$0,686 \pm 0,007$
1,600	[B40]	$3,36 \pm 0,08$	14,80	[B47]	$0,61 \pm 0,07$
2,000	[B40]	$2,96 \pm 0,07$	15,00	[B61]	$0,61$
2,140	[B15] [B18]	$2,76 \pm 0,06$	15,00	[B23]	$0,66 \pm 0,07$
2,280	[B15] [B18]	$2,70 \pm 0,06$	15,00	[B39]	$0,61$
2,400	[B13] [B14]	$2,28 \pm 0,09$	16,60	[B39]	$0,66$
2,400	[B15] [B18]	$2,50 \pm 0,06$	18,00	[B39]	$0,55$
2,440	[B 7]	$2,10 \pm 0,20$	19,50	[B39]	$0,52$
2,500	[B9] [B73]	$1,80 \pm 0,40$	19,93	[B75]	$0,504 \pm 0,001$
2,530	[B34]	$2,19$	21,00	[B39]	$0,41$
2,590	[B15] [B18]	$2,50 \pm 0,06$	25,00	[B34] [B38]	$0,39 \pm 0,06$
2,600	[B40]	$2,60 \pm 0,05$	27,00	[B62]	$0,36$
2,760	[B15] [B18]	$2,40 \pm 0,06$	39,00	[B64]	$0,223 \pm 0,07$
2,800	[B12]	$2,17 \pm 0,10$	40,00	[B50]	$0,170$
2,800	[B20]	$2,36 \pm 0,06$	64,50	[B65]	$0,126 \pm 0,003$
2,900	[B 9]	$1,80 \pm 0,20$	90,00	[B47]	$0,083 \pm 0,004$
3,000	[B40]	$2,33 \pm 0,13$	90,00	[B50]	$0,080 \pm 0,010$
3,100	[B58]	$2,18 \pm 0,13$	95,00	[B54] [B59]	$0,073 \pm 0,0015$
3,500	[B40]	$2,09 \pm 0,09$	97,00	[B68]	$0,074 \pm 0,010$
4,00	[B40]	$1,85 \pm 0,09$	117,00	[B68]	$0,0616$
4,10	[B43]	$1,73 \pm 0,06$	140,00	[B68]	$0,0485$
4,50	[B40]	$1,83 \pm 0,10$	156,00	[B64] [B65] [B68]	$0,0493$
4,75	[B72]	$1,69 \pm 0,06$	160,00	[B59]	$0,0512$
5,00	[B40]	$1,63 \pm 0,05$	169,00	[B77]	$0,0492 \pm 0,0016$
5,50	[B40]	$1,48 \pm 0,06$	180,00	[B68]	$0,044$
6,00	[B40]	$1,32 \pm 0,12$	220,00	[B59] [B68]	$0,0411$
6,50	[B46]	$1,40 \pm 0,11$	260,00	[B55]	$0,035$
9,30	[B46]	$0,92 \pm 0,08$	270,00	[B57] [B59]	$0,038 \pm 0,0015$
10,60	[B46]	$0,78 \pm 0,08$	280,00	[B56]	$0,036$
12,50	[B43]	$0,69 \pm 0,10$	400,00	[B74]	$0,0336$
12,80	[B23]	$0,83 \pm 0,09$			

## APPENDICE

## Sezioni d'urto differenziali protone-protone

$$Energia = 0.355 - 0.415 \text{ MeV.}$$

D. J. COOPER, D. H. FRISH e R. L. ZIMMERMANN: *Phys. Rev.*, **94**, 1209 (1954).

Energia	0,355	0,360	0,365	0,367	0,370	0,372	0,375	0,377
$\sigma_{\text{lab}} (45^\circ)$ in mb/ster.	7,5	7,0	5,0	4,0	4,0	3,8	3,2	3,0
$\sigma_{\text{c.m.}} (90^\circ)$ in mb/ster.	2,6	2,5	1,8	1,4	1,4	1,3	1,1	1,0

Energia	0,385	0,395	0,400	0,402	0,403	0,404	0,407	0,410	0,415
$\sigma_{\text{lab}} (45^\circ)$ in mb/ster.	2,8	3,2	3,4	4,0	4,4	4,2	5,1	5,7	6,8
$\sigma_{\text{c.m.}} (90^\circ)$ in mb/ster.	1,0	1,1	1,2	1,4	1,6	1,5	1,8	2,0	2,4

$$Energia = 9,7 \text{ MeV.}$$

B. CORK e W. HARTSOUGH: *Phys. Rev.*, **94**, 1300 (1954).

$\vartheta$	$\sigma_{\text{lab}} (\vartheta)$ in mb/ster.	$\Theta$	$\sigma_{\text{c.m.}} (\Theta)$ in mb/ster.
13,765°	217,3 $\pm$ 1,9	27,53°	55,95 $\pm$ 0,50
20,130°	197,0 $\pm$ 1,6	40,26°	52,46 $\pm$ 0,43
24,900°	195,3 $\pm$ 2,0	49,80°	53,89 $\pm$ 0,54
29,815°	190,9 $\pm$ 1,7	59,63°	55,06 $\pm$ 0,49
30,065°	191,6 $\pm$ 2,1	60,13°	55,38 $\pm$ 0,60
34,115°	181,4 $\pm$ 1,6	68,23°	54,84 $\pm$ 0,49
39,865°	165,6 $\pm$ 1,4	79,73°	53,91 $\pm$ 0,47
45,415°	158,8 $\pm$ 1,4	90,83°	56,11 $\pm$ 0,51
56,280°	120,8 $\pm$ 1,6	112,56°	54,52 $\pm$ 0,73

$$Energia = 18 \text{ MeV.}$$

J. L. YNTEMA e M. G. WHITE: *Phys. Rev.*, **95**, 1226 (1954).

$\vartheta$	$\sigma_{\text{lab}} (\vartheta)$ in mb/ster.	$\Theta$	$\sigma_{\text{c.m.}} (\Theta)$ in mb/ster.
15°	96,60 $\pm$ 0,97	30°	25,07 $\pm$ 0,25
18°	98,83 $\pm$ 0,99	36°	25,98 $\pm$ 0,26
20°	99,64 $\pm$ 0,79	40°	26,50 $\pm$ 0,21
25°	98,83 $\pm$ 0,69	50°	27,27 $\pm$ 0,19
30°	94,98 $\pm$ 0,55	60°	27,42 $\pm$ 0,16
35°	89,99 $\pm$ 0,46	70°	27,47 $\pm$ 0,14
40°	83,62 $\pm$ 0,43	80°	27,29 $\pm$ 0,14
45°	77,32 $\pm$ 0,40	90°	27,32 $\pm$ 0,14

*Energia* = 40 - 95 MeV.U. E. KRUSE, J. M. TEEM e N. F. RAMSEY: *Phys. Rev.*, **94**, 1795 (1954).

Energia	40	50	70	80	95	Energia	40	50	70	80	95
$\vartheta$	$\sigma_{\text{lab}} (\vartheta)$ in mb/ster.					$\Theta$	$\sigma_{\text{c.m.}} (\Theta)$ in mb/ster.				
20,00°	—	—	—	—	18,4	40,0°	—	—	—	—	4,90
21,25°	—	—	—	—	18,3	42,5°	—	—	—	—	4,92
25,00°	—	—	—	—	17,4	50,0°	—	—	—	—	4,80
30,90°	—	—	—	—	16,6	60,0°	—	—	—	—	4,79
31,25°	—	—	—	—	16,4	62,5°	—	—	—	—	4,80
35,00°	—	—	—	—	15,2	70,0°	—	—	—	—	4,65
36,25°	—	—	—	—	15,3	72,5°	—	—	—	—	4,75
40,00°	—	—	—	—	13,8	80,0°	—	—	—	—	4,50
45,00°	—	—	—	—	13,2	90,0°	—	—	—	—	4,65
46,25°	31,1	25,5	16,9	14,7	12,6	92,5°	11,0	9,0	6,0	5,2	4,50

*Energia* = 170 - 260 MeV.O. CHAMBERLAIN e J. D. GARRISON: *Phys. Rev.*, **95**, 1349 (1954).

Energia	170	260	Energia	170	260
$\vartheta$	$\sigma_{\text{lab}} (\vartheta)$ in mb/ster.		$\Theta$	$\sigma_{\text{c.m.}} (\Theta)$ in mb/ster.	
4,5°	20,4	23,1	9°	5,1	5,8
5,0°	16,7	17,5	10°	4,2	4,4
7,5°	15,1	15,5	15°	3,8	3,9
11,0°	14,9	15,7	22°	3,8	4,0
16,0°	15,0	15,0	32°	3,9	3,9
21,0°	14,2	14,6	42°	3,8	3,9
31,0°	12,3	13,4	62°	3,6	3,9

*Energia* = 300 MeV.O. CHAMBERLAIN, G. PETTENGILL, E. SEGRÉ e C. WIEGAND: *Phys. Rev.*, **95**, 1348 (1954).

$\vartheta$	$\sigma_{\text{lab}} (\vartheta)$ in mb/ster.	$\Theta$	$\sigma_{\text{c.m.}} (\Theta)$ in mb/ster.
3,5°	39,9	7°	10,0
4,0°	29,9	8°	7,5
4,5°	20,0	9°	5,0
5,5°	17,9	11°	4,5
6,5°	15,9	13°	4,0
8,5°	15,8	17°	4,0
11,0°	15,7	22°	4,0



$$Energia = 330 \text{ MeV.}$$

D. FISCHER e G. GOLDBABER: *Phys. Rev.*, **95**, 1350 (1954).

$\vartheta$	$\sigma_{lab}(\vartheta)$ in mb/ster.	$\Theta$	$\sigma_{c.m.}(\Theta)$ in mb/ster.
2,50°	136,0	5,0°	34,0
2,75°	76,9	5,5°	19,0
3,00°	60,9	6,0°	15,0
3,50°	36,0	7,0°	9,0
3,75°	24,0	7,5°	6,0
4,50°	16,0	9,0°	4,0
4,75°	14,0	9,5°	3,5
5,00°	12,0	10,0°	3,0
5,50°	12,0	11,0°	3,0
6,50°	14,0	13,0°	3,5
7,50°	14,0	15,0°	3,5
8,50°	15,8	17,0°	4,0
9,75°	13,8	19,5°	3,5
10,50°	15,7	21,0°	4,0
11,50°	13,7	23,0°	3,5
12,00°	13,7	24,0°	3,5
13,00°	13,6	26,0°	3,5
14,00°	13,6	28,0°	3,5
14,75°	13,5	29,5°	3,5

$$Energia = 364 - 428 \text{ MeV.}$$

A. J. HARTZLER, R. T. SIEGEL e W. OPITZ: *Phys. Rev.*, **95**, 591 (1954).

Sezione d'urto differenziale, nel s.c.m., praticamente costante al variare dell'angolo da 30° a 140°.

### Sezioni d'urto differenziali neutrone-protone

$$Energia = 14,1 \text{ MeV.}$$

J. R. SMITH: *Phys. Rev.*, **95**, 730 (1954).

Sezione d'urto differenziale, nel s.c.m., praticamente costante al variare dell'angolo da 20° a 180°.

$$Energia = 90 \text{ MeV.}$$

O. CHAMBERLAIN e J. W. EASLY: *Phys. Rev.*, **94**, 208 (1954).

$\vartheta$	$\sigma_{lab}(\vartheta)$ in mb/ster.	$\Theta$	$\sigma_{c.m.}(\Theta)$ in mb/ster.
2,55°	51,5 ± 5,1	5,1°	12,9 ± 1,2
5,15°	47,8 ± 2,8	10,3°	12,0 ± 0,7
10,40°	40,5 ± 2,4	20,8°	10,3 ± 0,6
18,00°	28,9 ± 1,5	36,0°	7,6 ± 0,4

*Energia* = 300 MeV.J. DE PANGHER: *Phys. Rev.*, **95**, 578 (1954).

$\Theta$	$\sigma_{\text{c.m.}} (\Theta)$ in mb/ster.	$\Theta$	$\sigma_{\text{c.m.}} (\Theta)$ in mb/ster.
10° - 20°	3,83 $\pm$ 0,63	100° - 110°	2,07 $\pm$ 0,16
20° - 30°	3,48 $\pm$ 0,47	110° - 120°	2,17 $\pm$ 0,17
30° - 40°	3,81 $\pm$ 0,41	120° - 130°	2,51 $\pm$ 0,19
40° - 50°	3,50 $\pm$ 0,35	130° - 140°	3,06 $\pm$ 0,23
50° - 60°	2,96 $\pm$ 0,29	140° - 150°	4,06 $\pm$ 0,29
60° - 70°	2,31 $\pm$ 0,23	150° - 160°	4,71 $\pm$ 0,37
70° - 80°	2,02 $\pm$ 0,20	160° - 170°	6,48 $\pm$ 0,55
80° - 90°	1,89 $\pm$ 0,18	170° - 180°	9,14 $\pm$ 1,12
90° - 100°	1,51 $\pm$ 0,14		

*Energia* = 400 MeV.A. J. HARTZLER e R. T. SIEGEL: *Phys. Rev.*, **95**, 185 (1954).A. J. HARTZLER, R. T. SIEGEL e W. OPITZ: *Phys. Rev.*, **95**, 591 (1954).

$\varphi = (\pi/2) - \vartheta$	$\sigma_{\text{lab}} (\varphi)$ in mb/ster.	$\Theta$	$\sigma_{\text{c.m.}} (\Theta)$ in mb/ster.
82,0°	6,64 $\pm$ 0,56	12,7°	3,73 $\pm$ 2,10
81,3°	6,91 $\pm$ 0,80	15,0°	4,43 $\pm$ 0,46
79,0°	4,04 $\pm$ 0,52	20,0°	3,07 $\pm$ 0,37
73,5°	3,18 $\pm$ 0,62	30,0°	2,84 $\pm$ 0,57
68,2°	4,30 $\pm$ 0,30	40,0°	3,33 $\pm$ 0,20
65,5°	4,88 $\pm$ 0,30	45,0°	3,35 $\pm$ 0,20
63,2°	5,42 $\pm$ 0,20	50,0°	3,38 $\pm$ 0,12
60,2°	4,58 $\pm$ 0,40	55,0°	2,56 $\pm$ 0,23
57,6°	4,88 $\pm$ 0,16	60,0°	2,48 $\pm$ 0,08
52,4°	5,13 $\pm$ 0,21	70,0°	2,22 $\pm$ 0,09
47,2°	4,90 $\pm$ 0,18	80,0°	1,85 $\pm$ 0,06
42,4°	4,58 $\pm$ 0,20	90,0°	1,54 $\pm$ 0,06
37,4°	4,70 $\pm$ 0,18	100,0°	1,42 $\pm$ 0,06
32,6°	5,43 $\pm$ 0,25	110,0°	1,50 $\pm$ 0,08
27,8°	7,60 $\pm$ 0,40	120,0°	1,94 $\pm$ 0,08
23,0°	10,46 $\pm$ 0,45	130,0°	2,50 $\pm$ 0,09
18,5°	14,14 $\pm$ 0,45	140,0°	3,21 $\pm$ 0,09
13,8°	19,12 $\pm$ 0,50	150,0°	4,17 $\pm$ 0,11
9,1°	24,80 $\pm$ 0,60	160,0°	5,25 $\pm$ 0,14
6,8°	27,84 $\pm$ 1,10	165,0°	5,87 $\pm$ 0,22
4,6°	38,12 $\pm$ 1,20	170,0°	7,93 $\pm$ 0,28
2,3°	46,23 $\pm$ 1,70	175,0°	9,57 $\pm$ 0,34
0,0°	65,16 $\pm$ 4,50	180,0°	13,49 $\pm$ 0,91

## Sezioni d'urto totali neutrone-protone.

Energia (MeV)	Bibliografia	$\sigma_{\text{tot}}$ in barn
1,32	C. L. STORRS e D. H. FRISH: <i>Phys. Rev.</i> , <b>95</b> , 1252 (1954)	$3,675 \pm 0,020$
14,1	C. F. COOK e T. W. BONNER: <i>Phys. Rev.</i> , <b>94</b> , 651 (1954)	$0,690 \pm 0,012$
15,0	» » »	$0,662 \pm 0,010$
15,5	» » »	$0,648 \pm 0,012$
16,0	» » »	$0,582 \pm 0,030$
16,5	» » »	$0,609 \pm 0,015$
17,0	» » »	$0,612 \pm 0,030$
17,5	» » »	$0,587 \pm 0,020$
18,0	» » »	$0,539 \pm 0,015$
42	R. H. HILDEBRAND e C. E. LEITH: <i>Phys. Rev.</i> , <b>89</b> , 842 (1950)	$0,203 \pm 0,007$
$94,8 \pm 1,5$	V. CULLER e R. W. WANIEK: <i>Phys. Rev.</i> , <b>95</b> , 585 (1954)	$0,077 \pm 0,003$
$98,6 \pm 2,5$	» » »	$0,076 \pm 0,005$
$102,0 \pm 7,6$	» » »	$0,080 \pm 0,007$
$107,9 \pm 5,0$	» » »	$0,059 \pm 0,016$
400	A. J. HARTZLER e R. T. SIEGEL: <i>Phys. Rev.</i> , <b>95</b> , 185 (1954)	0,034
410	A. NEDZEL: <i>Phys. Rev.</i> , <b>94</b> , 174 (1954)	$0,0337 \pm 0,0013$

## BIBLIOGRAFIA

## A) Protone-protone.

- [A 1] W. H. WELLS: *Phys. Rev.*, **47**, 591 (1935).  
[A 2] M. G. WHITE: *Phys. Rev.*, **49**, 309 (1936).  
[A 3] M. A. TUVE, N. P. HEIDENBURG e L. R. HAFSTAD: *Phys. Rev.*, **50**, 806 (1936).  
[A 4] L. R. HAFSTAD, N. P. HEIDENBURG e M. A. TUVE: *Phys. Rev.*, **53**, 239 (1938).  
[A 5] R. G. HERB, D. W. KERST, D. B. PARKINSON e G. J. PLAIN: *Phys. Rev.*, **55**, 603 (1939).  
[A 6] R. G. HERB, D. W. KERST, D. B. PARKINSON e G. J. PLAIN: *Phys. Rev.*, **55**, 998 (1939).  
[A 7] N. P. HEIDENBURG, L. R. HAFSTAD e M. A. TUVE: *Phys. Rev.*, **56**, 1078 (1939).  
[A 8] G. L. RAGAN, W. R. KANNE e R. F. TASHEK: *Phys. Rev.*, **60**, 628 (1941).  
[A 9] R. R. WILSON e C. E. CREUTZ: *Phys. Rev.*, **71**, 339 (1947).

- [A 10] R. R. WILSON: *Phys. Rev.*, **71**, 384 (1947).
- [A 11] R. R. WILSON, E. J. LOFGREN, J. R. RICHARDSON, B. T. WRIGHT e R. S. SHANKLAND: *Phys. Rev.*, **71**, 560 (1947).
- [A 12] R. R. WILSON, E. J. LOFGREN, J. R. RICHARDSON, B. T. WRIGHT e R. S. SHANKLAND: *Phys. Rev.*, **72**, 1131 (1947).
- [A 13] A. MAY e C. POWELL: *Proc. Roy. Soc.*, A **190**, 170 (1947).
- [A 14] W. SLEATOR jun., J. M. BLAIR, E. E. LAMPI e J. H. WILLIAMS: *Phys. Rev.*, **73**, 1241 (1948).
- [A 15] I. H. DEARNLEY, C. L. OXLEY e J. E. PERRY jun.: *Phys. Rev.*, **73**, 1290 (1948).
- [A 16] J. M. BLAIR, G. FREIER, E. E. LAMPI, W. SLEATOR jun. e J. H. WILLIAMS: *Phys. Rev.*, **74**, 553 (1948).
- [A 17] J. M. BLAIR, G. FREIER, E. E. LAMPI, W. SLEATOR jun. e J. W. WILLIAMS: *Phys. Rev.*, **74**, 1205 (1948).
- [A 18] R. O. BONDELID, P. G. BOHLMAN e K. B. MATHER: *Phys. Rev.*, **76**, 865 (1949).
- [A 19] C. WIEGAND e O. CHAMBERLAIN: *Phys. Rev.*, **78**, 326 (1950).
- [A 20] R. E. MEAGHER: *Phys. Rev.*, **78**, 667 (1950).
- [A 21] W. K. H. PANOFSKY e F. L. FILLMORE: *Phys. Rev.*, **79**, 57 (1950).
- [A 22] B. CORK, L. JOHNSTON e C. RICHMAN: *Phys. Rev.*, **79**, 71 (1950).
- [A 23] O. CHAMBERLAIN e C. WIEGAND: *Phys. Rev.*, **79**, 81 (1950).
- [A 24] F. E. FARIS e B. T. WRIGHT: *Phys. Rev.*, **79**, 577 (1950).
- [A 25] B. CORK: *Phys. Rev.*, **80**, 321 (1950).
- [A 26] O. CHAMBERLAIN, E. SEGRÈ e C. WIEGAND: *Phys. Rev.*, **81**, 284 (1951).
- [A 27] J. ROUVINA: *Phys. Rev.*, **81**, 593 (1951).
- [A 28] K. B. MATHER: *Phys. Rev.*, **82**, 133 (1951).
- [A 29] C. L. OXLEY, R. D. SCHAMBERGER e O. A. TOWLER jun.: *Phys. Rev.*, **82**, 295 (1951).
- [A 30] E. J. ZIMMERMANN e P. G. KRUGER: *Phys. Rev.*, **83**, 218 (1951).
- [A 31] O. CHAMBERLAIN, E. SEGRÈ e C. WIEGAND: *Phys. Rev.*, **83**, 218 (1951).
- [A 32] R. W. BIRGE, U. E. KRUSE e N. F. RAMSEY: *Phys. Rev.*, **83**, 274 (1951).
- [A 33] J. CASSELS, T. PICKAVANCE e G. STAFFORD: *Univ. of Chicago conf.*, (1951), pag. 96.
- [A 34] O. CHAMBERLAIN, E. SEGRÈ e C. WIEGAND: *Phys. Rev.*, **83**, 923 (1951).
- [A 35] F. L. FILLMORE: *Phys. Rev.*, **83**, 1252 (1951).
- [A 36] O. A. TOWLER jun.: *Phys. Rev.*, **84**, 1262 (1951).
- [A 37] C. L. OXLEY e R. D. SCHAMBERGER: *Phys. Rev.*, **85**, 416 (1952).
- [A 38] O. A. TOWLER jun.: *Phys. Rev.*, **85**, 1024 (1952).
- [A 39] R. O. BONDELID, C. H. BRADEN, M. E. BATTAT e P. BOHLMAN: *Phys. Rev.*, **87**, 699 (1952).
- [A 40] J. C. ALLRED, A. H. ARMSTRONG, R. O. BONDELID e L. ROSEN: *Phys. Rev.*, **88**, 433 (1952).
- [A 41] R. O. KERMAN, W. E. KREGER e P. G. KRUGER: *Phys. Rev.*, **89**, 908 (1953).
- [A 42] J. L. YNTEMA e M. G. WHITE: dati non pubblicati, riportati da A. MARTIN e L. VERLET: *Phys. Rev.*, **89**, 519 (1953).
- [A 43] W. E. MOTT, R. B. SUTTON, J. G. FOX e J. A. KANE: *Phys. Rev.*, **90**, 712 (1953).
- [A 44] H. R. WORTHINGTON, J. N. MCGRUERE e D. E. FINDLEY: *Phys. Rev.*, **90**, 899 (1953).
- [A 45] R. L. ZIMMERMANN, D. H. FRISH e D. I. COOPER: *Phys. Rev.*, **90**, 339 (1953).
- [A 46] J. MARSHALL, L. MARSHALL e V. A. NEDZEL: *Phys. Rev.*, **91**, 767 (1953).
- [A 47] CLARK, GRANDEY, GANS e MANN: valori riportati da J. MARSHALL, L. MARSHALL e V. A. NEDZEL: *Phys. Rev.*, **91**, 767 (1953).



- [A 48] Berkeley: comunicazione privata di O. CHAMBERLAIN a J. MARSHALL, L. MARSHALL e V. A. NEDZEL: *Phys. Rev.*, **91**, 767 (1953).
- [A 49] J. MARSHALL, L. MARSHALL e V. A. NEDZEL: *Phys. Rev.*, **92**, 834 (1953).
- [A 50] R. L. ZIMMERMANN, D. H. FRISH e D. I. COOPER: *Bull. of Am. Phys. Soc.*, **29**, n. 4, 74 (1954).
- [A 51] U. E. KRUSE e J. M. TEEM: *Bull. of Am. Phys. Soc.*, **29**, n. 4, 74 (1954).
- [A 52] S. K. KAO e A. F. CLARK: *Bull. of Am. Phys. Soc.*, **29**, n. 4, 74 (1954).
- [A 53] J. A. KANE, R. A. STALLWOOD, R. B. SUTTON, T. H. FIELDS e J. G. FOX: *Bull. of Am. Phys. Soc.*, **29**, n. 4, 74 (1954).
- [A 54] R. B. SUTTON, T. H. FIELDS, J. A. KANE, W. E. MOTT e T. A. STALLWOOD: *Bull. of Am. Phys. Soc.*, **29**, n. 4, 75 (1954).
- [A 55] A. M. SHAPIRO, C. P. LEAVIT e F. F. CHEN: *Bull. of Am. Phys. Soc.*, **29**, n. 4, 75 (1954).
- [A 56] O. CHAMBERLAIN, G. PETTENGILL, E. SEGRÈ e C. WIEGAND: *Phys. Rev.*, **93**, 1424 (1954).

### B) Neutrone-protone.

- [B 1] J. KURIE: *Phys. Rev.*, **44**, 641 (1933).
- [B 2] L. MODON-HERTZEN: *Journ. de Phys. et Rad.*, (Febr. 1934).
- [B 3] W. D. HARKINS, D. M. GANS, M. D. KAMMEN e H. W. NEWSON: *Phys. Rev.*, **47**, 511 (1935).
- [B 4] W. D. HARKINS, D. M. GANS: *Phys. Rev.*, **47**, 795 (1935).
- [B 5] M. A. TUVE e L. R. HAFSTAD: *Phys. Rev.*, **50**, 490 (1937).
- [B 6] P. G. KRUGER, W. E. SHOUPP e F. W. STALLMAN: *Phys. Rev.*, **52**, 678 (1937).
- [B 7] R. LANDENBURG e M. H. KANNER: *Phys. Rev.*, **52**, 911 (1937).
- [B 8] T. BONNER: *Phys. Rev.*, **52**, 685 (1937).
- [B 9] E. T. BOOTH e C. HURST: *Proc. Phys. Mat.*, A **161**, 248 (1937).
- [B 10] F. FEDOROV e A. PERFILIEVA: *Sovietphys.*, **2**, 660 (1937).
- [B 11] P. DEE e C. GILBERT: *Proc. Roy. Soc.*, A **163**, 265 (1937).
- [B 12] W. H. ZINN, S. SEELY e V. W. COHEN: *Phys. Rev.*, **53**, 921 (1938).
- [B 13] S. KIKUCHI e H. AOKI: *Phys. Rev.*, **55**, 108 (1939).
- [B 14] H. AOKI: *Proc. Phys. Mat. Soc. J.*, **21**, 232 (1939).
- [B 15] H. AOKI: *Phys. Rev.*, **55**, 795 (1939).
- [B 16] E. O. SALANT, R. B. ROBERTS e P. WANG: *Phys. Rev.*, **55**, 984 (1939).
- [B 17] E. AMALDI, D. BOCCIARELLI, B. FERRETTI e G. TRABACCHI: *Ric. Scient.*, **10**, 633 (1939).
- [B 18] S. KIKUCHI, H. AOKI e A. WAKATSUKI: *Proc. Phys. Mat. Soc. J.*, **21**, 410 (1939).
- [B 19] A. LEIPUNSKI: *Sov. Phys. USSR*, **110**, 625 (1939).
- [B 20] W. H. ZINN, S. SEELY e W. COHEN: *Phys. Rev.*, **56**, 260 (1940).
- [B 21] E. AMALDI, D. BOCCIARELLI, B. FERRETTI e G. TRABACCHI: *Phys. Rev.*, **56**, 881 (1940).
- [B 22] T. GOLOBORODKO e A. LEIPUNSKI: *Phys. Rev.*, **56**, 891 (1940).
- [B 23] E. O. SALANT e N. F. RAMSEY: *Phys. Rev.*, **57**, 1075 (1940).
- [B 24] E. AMALDI, D. BOCCIARELLI e G. TRABACCHI: *Ric. Scient.*, **11**, 121 (1940).
- [B 25] W. E. GOOD, G. SHARFF-GOLDHABER: *Phys. Rev.*, **58**, 89 (1940).
- [B 26] H. H. BARSHALL e M. H. KANNER: *Phys. Rev.*, **58**, 590 (1940).
- [B 27] W. E. GOOD, G. SHARFF-GOLDHABER: *Phys. Rev.*, **59**, 917 (1940).

# SOCIETÀ ITALIANA DI FISICA

---

## SUBSCRIPTIONS TO "IL NUOVO CIMENTO" AND MEMBERSHIP FEES FOR 1955

Subscription rates to IL NUOVO CIMENTO and SUPPLEMENTO:

<i>For Italy</i>	{ normal subscription . . . . .	6.000 lire
	{ sponsoring subscription . . . . .	25.000 lire at least
<i>For foreign countries</i> . . . . .		6.500 lire

Membership fees:

<i>For Italy</i>	{ individual members . . . . .	5.000 lire
	{ organizations . . . . .	10.000 lire
	{ sponsoring members . . . . .	25.000 lire at least
<i>For foreign countries</i> . . . . .		5.500 lire

To members of the Società Italiana di Fisica IL NUOVO CIMENTO and the SUPPLEMENTO are sent free of charge.

Membership fees and subscription rates are to be paid to the Publisher - Nicola Zanichelli - Bologna, Via Irnerio 34, directly or through a bookseller.

---

Members and subscribers are kindly requested to see timely to the payment for 1955 in order to avoid suspension of the regular dispatch of the review.

(voltare)

**ABBONAMENTI A "IL NUOVO CIMENTO"**

**E QUOTE SOCIALI PER IL 1955**

**Prezzi di abbonamento al NUOVO CIMENTO e relativo SUPPLEMENTO:**

<i>Per l'Italia</i>	{	abbonamento ordinario . . . . .	L. 6.000
		abbonamento sostenitore . . . . .	» 25.000 almeno
<i>Per l'estero</i>	-	abbonamento ordinario . . . . .	» 6.500

**Quote sociali:**

<i>Per l'Italia</i>	{	socio individuale . . . . .	L. 5.000
		socio collettivo . . . . .	» 10.000
		socio sostenitore . . . . .	» 25.000 almeno
<i>Per l'estero</i>	-	socio individuale . . . . .	» 5.500

Ai soci della Società Italiana di Fisica IL NUOVO CIMENTO e il SUPPLEMENTO sono inviati gratuitamente.

Le somme per l'abbonamento e le quote di associazione vanno pagate (queste direttamente, quelle o direttamente o per mezzo di un libraio) all'Editore Nicola Zanichelli, - Bologna, Via Irnerio, 34 (C/c postale 8/36).

---

Per evitare la sospensione dell'invio del Giornale si pregano i soci e gli abbonati di provvedere con sollecitudine ai pagamenti per il 1955.

*(turn, please)*

- [B 28] C. POWELL, H. HEITLER e F. CHAMPION: *Proc. Roy. Soc., A* **1**, 150 (1940).  
[B 29] A. LEIPUNSKI: *Journ. Phys. USSR*, **3**, 231 (1940).  
[B 30] A. WAKATSUKI: *Proc. Phys. Mat. Soc. J.*, **22**, 430 (1940).  
[B 31] C. POWELL, H. HEITLER e F. CHAMPION: *Nature*, **146**, 716 (1940).  
[B 32] E. AMALDI, D. BOCCIARELLI, B. FERRETTI e G. TRABACCHI: *Ric. Scient.*, **12**, 830 (1941).  
[B 33] H. TATEL: *Phys. Rev.*, **61**, 450 (1942).  
[B 34] R. SHERR: *Phys. Rev.*, **61**, 734 (1942).  
[B 35] E. AMALDI, D. BOCCIARELLI, B. FERRETTI e G. TRABACCHI: *Ric. Scient.*, **13**, 502 (1942).  
[B 36] E. AMALDI, D. BOCCIARELLI, B. FERRETTI e G. TRABACCHI: *Naturwiss.*, **30**, 582 (1942).  
[B 37] T. GOLOBORODKO: *Journ. Phys. USSR*, **8**, (1944).  
[B 38] R. SHERR: *Phys. Rev.*, **68**, 240 (1946).  
[B 39] W. SLEATOR jun.: *Phys. Rev.*, **69**, 681 (1946).  
[B 40] C. L. BAILEY, W. E. BENNET, T. BERGSTRAHL, R. G. NUCKOLLS, T. H. RICHARDS e J. H. WILLIAMS: *Phys. Rev.*, **70**, 583 (1946).  
[B 41] D. H. FRISH: *Phys. Rev.*, **70**, 589 (1946).  
[B 42] D. H. FRISH: *Phys. Rev.*, **70**, 792 (1946).  
[B 43] M. AGENO, E. AMALDI, D. BOCCIARELLI e G. TRABACCHI: *Phys. Rev.*, **71**, 20 (1947).  
[B 44] A. WATTENBERG: *Phys. Rev.*, **71**, 497 (1947).  
[B 45] J. S. LAUGHLIN e P. G. KRUGER: *Phys. Rev.*, **71**, 736 (1947).  
[B 46] W. SLEATOR jun.: *Phys. Rev.*, **72**, 207 (1947).  
[B 47] L. J. COOK, E. M. McMILLAN, J. M. PETERSON e D. C. SEWELL: *Phys. Rev.*, **72**, 1264 (1947).  
[B 48] J. S. LAUGHLIN e P. G. KRUGER: *Phys. Rev.*, **73**, 197 (1948).  
[B 49] J. HADLEY, E. L. KELLY, C. E. LEITH, E. SEGRÈ, C. WIEGAND e H. F. YORK: *Phys. Rev.*, **73**, 114 (1948).  
[B 50] L. J. COOK, E. M. McMILLAN, J. M. PETERSON e D. C. SEWELL: *Phys. Rev.*, **75**, 7 (1949).  
[B 51] J. HADLY, E. L. KELLY, C. E. LEITH, E. SEGRÈ, C. WIEGAND e H. F. YORK: *Phys. Rev.*, **75**, 351 (1949).  
[B 52] K. BRUECKNER, W. HARTSOUGH, E. HAYWARD e W. M. POWELL: *Phys. Rev.*, **75**, 555 (1949).  
[B 53] E. E. LAMPI, G. FREIER e J. H. WILLIAMS: *Phys. Rev.*, **76**, 188 (1950).  
[B 54] J. DE JUREN e N. KNABLE: *Phys. Rev.*, **77**, 606 (1950).  
[B 55] E. KELLY, G. LEITH, E. SEGRÈ e C. WIEGAND: *Phys. Rev.*, **79**, 96 (1950).  
[B 56] R. FOX, C. E. LEITH e L. WOUTERS: *Phys. Rev.*, **80**, 23 (1950).  
[B 57] J. DE JUREN: *Phys. Rev.*, **80**, 27 (1950).  
[B 58] Y. ODA, J. SAHADA e S. YAMABE: *Phys. Rev.*, **80**, 469 (1950).  
[B 59] J. DE JUREN e B. J. MOYER: *Phys. Rev.*, **81**, 919 (1951).  
[B 60] R. WALLACE: *Phys. Rev.*, **81**, 494 (1951).  
[B 61] A. H. LASDAY: *Phys. Rev.*, **81**, 139, (1951).  
[B 62] J. E. BROLLEY jun., J. H. COON e J. L. FOWLER: *Phys. Rev.*, **82**, 190 (1951).  
[B 63] E. M. BALDWIN: *Phys. Rev.*, **83**, 495 (1951).  
[B 64] A. E. TAYLOR, T. G. PICKAVANCE, J. M. CASSELS e T. C. RANDLE: *Phil. Mag.*, **42**, 751 (1951).  
[B 65] A. E. TAYLOR, T. G. PICKAVANCE, J. M. CASSELS e T. C. RANDLE: *Phil. Mag.*, **42**, 328 (1951).



- [B 66] H. L. POSS, E. O. SALANT, e L. C. L. YUAN: *Phys. Rev.*, **85**, 703 (1952).
- [B 67] H. L. POSS, E. O. SALANT e L. C. L. YUAN: *Phys. Rev.*, **87**, 11 (1952).
- [B 68] G. R. MOTT, G. L. GUERSNEY e B. K. NELSON: *Phys. Rev.*, **88**, 9 (1952).
- [B 69] G. R. MOTT, G. L. GUERSNEY e B. K. NELSON: *Phys. Rev.*, **88**, 15 (1952).
- [B 70] L. S. GOODMAN: *Phys. Rev.*, **88**, 686 (1952).
- [B 71] J. H. COON, E. R. GRAVES e H. H. BARSHALL: *Phys. Rev.*, **88**, 562 (1952).
- [B 72] E. M. HAFNER, W. F. HORNYAK, G. SCHAW e T. COOR: *Phys. Rev.*, **89**, 204 (1952).
- [B 73] R. E. FIELDS, R. L. BECKER e R. K. ADANI: *Phys. Rev.*, **89**, 908 (1952).
- [B 74] V. A. NEDZEL: *Phys. Rev.*, **99**, 169 (1953).
- [B 75] R. B. DAY e R. L. HENKEL: *Phys. Rev.*, **92**, 358 (1953).
- [B 76] W. SELOVE, K. STRAUCH e F. TITUS: *Phys. Rev.*, **92**, 724 (1953).
- [B 77] A. E. TAYLOR: *Phys. Rev.*, **92**, 1071 (1953).
- [B 78] R. H. STAHL: *Bull. of Am. Phys. Soc.*, **29**, n. 4, 76 (1954).

## Tables for Simplifying Calculations of Activities Produced by Thermal Neutrons (\*).

F. E. SENFTLE and W. R. CHAMPION

*U.S. Geological Survey, Washington, D.C.*

(ricevuto il 2 Dicembre 1954)

---

CONTENTS: Introduction. — Method of Simplification. — The Tables. —  
Examples. — Conclusion.

---

### Introduction.

When various materials are to be bombarded by thermal neutrons in a pile or cyclotron, it is often desirable to have an estimate of the activity that may be expected after a given irradiation time at a known flux. The calculation is straightforward and, where only a few items are concerned, it is not exceedingly tedious. However, where these calculations have to be made regularly or where many calculations have to be made in a short time, it is expedient to simplify the calculation.

### Method of Simplification.

The activity produced in a given nuclide by thermal neutrons is

$$(1) \quad A_t = (\sigma f N k)(1 - \exp[-0.693 \cdot t/T]) \exp[-0.693 \cdot \theta/T],$$

---

(\*) This paper originally appeared in *Nucleonics*, 6, 54-63 (May, 1950), as *Table for Simplifying Calculations of Activities Produced by Thermal Neutrons*, by F. E. SENFTLE and W. Z. LEAVITT. Because of its usefulness for certain applications, it has been revised and recompiled to include new nuclear data that were available up to Nov. 1, 1954. Publication authorized by the Director, U.S. Geological Survey.

where

- $A_t$  = activity, in disintegrations per second (disint./s), of the radionuclide in a target, after the nuclide has been removed from the flux for a period  $\theta$ ;  
 $\sigma$  = activation cross section in square centimeters for 2200 m/s neutrons;  
 $f$  = thermal neutron flux in neutrons per square centimeter per second;  
 $N$  = the total number of atoms of the element in the target;  
 $k$  = relative abundance of the isotope from which the radionuclide is formed;  
 $t$  = time of irradiation;  
 $\theta$  = time of decay;  
 $T$  = half-life of radionuclide formed.

The usual procedure in making this calculation is to evaluate the terms in the parentheses by separate operations. The product  $(\sigma f N k)$  in equation (1) is the activity obtainable by an infinitely long irradiation period and is called the saturation activity. In all cases irradiation for periods that are greater than 10 half-lives will suffice to produce 99.9% saturation.

The saturation activity of any nuclide, as described above, will be characteristic for any given weight of the target element that is activated in a given flux, as the expression includes the relative abundance of the parent isotope. Therefore it appears logical, as a step toward simplification in calculating saturation activities, to have a prepared table based on fixed weight and flux values.

For convenience, the Tables presented in this paper (pag. 555-570) are based on 1 g of element being irradiated in a flux of  $10^{12}$  neutrons per  $\text{cm}^2$  per second. Thus the specific saturation activity, designated  $A_s$  in the Tables (column 9), is the product  $\sigma f_0 N_0 k$ , where  $N_0$  is the number of atoms of the element in 1 gram of the target and  $f_0$  is a flux of  $10^{12}$  neutrons/ $\text{cm}^2$  s.  $A_s$  is expressed in disint./s g.

In any given problem, if the flux differs from  $10^{12}$  neutrons per  $\text{cm}^2$  per second, the correct value may be obtained by multiplying by a suitable factor of proportionality. The corrected value of  $A_s$  for a particular experiment is simply

$$(2) \quad A'_s = \left[ \frac{fW}{10^{12}} \right] \cdot A_s,$$

where  $W$  is the weight of the element in the sample, and  $f$  is the flux.

In equation (1),  $(1 - \exp[-0.693 \cdot t/T])$  is the growth factor for the activity produced. By expanding the exponential it can be simplified

$$(3) \quad 1 - \exp[-0.693 \cdot t/T] \approx 0.693 \cdot t/T,$$

provided that  $t/T$  is small, say less than 0.15. Consequently, if  $t$  is less than about 15% of the half-life,  $0.693 \cdot t/T$  may be substituted for  $(1 - \exp[-0.693 \cdot t/T])$  without incurring an appreciable error, i.e., an error less than the probable error in the known cross sections.

To evaluate the growth and decay factors in equation (1) when  $t/T > 0.15$ , the Table is supplemented by a graph (Fig. 1, pag. 571). The growth factor  $(1 - \exp[-0.693 \cdot t/T])$ , has been plotted as a function of  $t/T$ , and the decay factor  $\exp[-0.693 \cdot \theta/T]$  as a function of  $\theta/T$ .

In general, equation (1) may be written

$$(4) \quad A_t = A'_s (1 - \exp[-0.693 \cdot t/T]) \exp[-0.693 \cdot \theta/T].$$

As a special case, where  $t$  is known to be less than 15% of  $T$ , a further simplification can be made:

$$A_t = A'_s \frac{0.693 t}{T} \exp[-0.693 \cdot \theta/T] = A'_s \lambda t \exp[-0.693 \cdot \theta/T],$$

where  $\lambda = 0.693/T$  is the decay constant. If  $t = 1$  s and  $\theta = 0$ , then  $A_t = A'_s \lambda$ . Therefore the product  $\bar{A}_t = A'_s \lambda$  is defined as the specific initial activity in 1 g of the target for 1 s period of irradiation with a flux of  $10^{12}$  neutrons/cm<sup>2</sup> s. The values of  $\bar{A}_t$ , in disint./s g, can be found in the Tables (column 10), and  $\exp[-0.693 \cdot \theta/T]$  is most easily obtained from the graph (Fig. 1).

In cases where  $t$  is greater than 15% of  $T$ , only the value  $A'_s$  can be taken from the Table,  $(1 - \exp[-0.693 \cdot t/T])$  and  $\exp[-0.693 \cdot \theta/T]$  must be obtained from the graph.

## The Tables.

The data used to calculate the saturation activities have been taken from some of the most recent publications of nuclear constants <sup>(1-5)</sup>. These fundamental data have been included in the Tables because the values of some of the constants, notably the data on cross sections, are continually changing with increased accuracy of measuring techniques. An estimate, therefore, of the value of the derived constants can easily be made.

(1) K. WAY, A. L. HAWKINS, R. W. KING, C. L. MCGINNIS and M. WOOD: *Nuclear Science Abstracts* by the National Research Council.

(2) J. M. HOLLANDER, I. PERLMAN and G. T. SEABORG: *Rev. Mod. Phys.*, **25**, 469 (1953).

(3) AEC Neutron Cross Section Advisory Group: *Neutron Cross Sections*, AECU-2040.

(4) D. J. HUGHES, R. C. GARTH, and J. S. LEVIN: *Phys. Rev.*, **91**, 1423 (1953).

(5) D. J. HUGHES: *Pile Neutron Research* (Cambridge, Mass., 1953).



The cross sections are for 2200 m/s neutrons, i.e., most of the nuclides involved have been measured and compared in a Maxwellian distribution of thermal neutrons with a nuclide whose cross section has been measured in a beam of 2200 m/s neutrons and which has a true  $1/v$  energy dependence. Where one is working with neutron energy distributions which are not Maxwellian, it is possible that the cross-section values may give misleading results. However, in such instances the results will probably not be in error by more than a factor of 2.

$A_s$  has been calculated to one more place than the value for  $\sigma$ , but  $A_s\lambda$  has been rounded off to the same number of places as  $\sigma$  or  $\lambda$ , whichever has the least number of significant figures. The type of decay and emission, and the daughter nuclides, if any, have been listed under «Notes» in the last column.

### Examples.

*Problem 1:* — How long must a 3 g gold foil be irradiated in a flux of  $10^8$  neutrons/cm<sup>2</sup>s to attain an activity of  $8 \cdot 10^7$  disintegrations per second? What is the activity 3 days after removal of the foil from the flux?

*Solution.* —  $A_i$  in equation (4) is  $8 \cdot 10^7$  disint./s.  $A_s$  from the table is  $2.93 \cdot 10^{11}$  disint./s g. As this value is based on 1 g of element and a flux of  $10^{12}$  neutrons/cm<sup>2</sup>s,  $2.93 \cdot 10^{11}$  must be multiplied by  $3 \cdot 10^{-4}$  to correct for weight and flux (see equation (2)). As it is desired to know the activity upon removal from the flux, the decay factor  $\exp[-0.693 \cdot \theta/T]$  is dropped from equation (4). Hence

$$8 \cdot 10^7 = 2.93 \cdot 10^{11} \cdot 3 \cdot 10^{-4} (1 - \exp[-0.693 \cdot t/T]),$$

$$1 - \exp[-0.693 \cdot t/T] = 0.91.$$

From the graph, 0.91 corresponds to a value of  $t/T = 3.45$ , and, since  $T$  is 2.73 days,  $t$  is 9.4 days.

To obtain the activity of the foil 3 days after removal from the flux, the total activity of  $8 \cdot 10^7$  disint./s need only be multiplied by the decay factor  $\exp[-0.693 \cdot \theta/T]$ , obtained from the curve.  $\theta/T$  for this decay period is  $(3/2.73) = 1.10$  and this corresponds to 0.465 on the graph. Thus, the activity after 3 days will be

$$A_t = 8 \cdot 10^7 \cdot 0.465 = 3.72 \cdot 10^7 \text{ disint./s.}$$

*Problem 2.* — A 0.5 g button of tungsten is placed in a flux of  $10^{11}$  neutrons/cm<sup>2</sup> s for 3 days. What is the activity due to the 24 hour and 73 day radionuclides which are produced upon removal from the flux?

*Solution.* — For 24 hour tungsten the ratio  $t/T$  is  $(72/24.1) = 2.99$ . This corresponds to a growth factor of 0.885 on the graph.  $A_s$  from the table is  $3.7 \cdot 10^{10}$  disint./s g. This has to be corrected for the weight of the tungsten button and the neutron flux. Thus substituting in equation (4),

$$A_t = 3.7 \cdot 10^{10} \cdot 0.5 \cdot 10^{-1} \cdot 0.885 = 1.59 \cdot 10^9 \text{ disint./s.}$$

For 73 day tungsten the ratio of  $t/T$  is less than 0.15 in this case, and therefore  $A_s \lambda$  can be used directly.  $A_s \lambda$  from the table is  $2.2 \cdot 10^2$  disint./s g. Therefore

$$A_t = A_s \lambda t = 2.2 \cdot 10^2 \cdot 0.5 \cdot 10^{-1} \cdot (3 \cdot 24 \cdot 60 \cdot 60) = 2.85 \cdot 10^6 \text{ disint./s.}$$

*Problem 3.* — What is the ratio of the activities due to sodium and potassium in a rock specimen immediately upon removal of the specimen from the pile? Assume that the specimen has been irradiated for a period of 1 day and that it contains 5% sodium and 2% potassium by weight.

*Solution.* — From the Table and the graph we obtain following results.

For sodium:

$$A_s = 1.39 \cdot 10^{10} \text{ or } 0.05 \cdot 1.39 \cdot 10^{10} \text{ (corrected),}$$

$$t/T = 24/15.06 = 1.60, \text{ which corresponds to } (1 - \exp[-0.693 \cdot t/T]) = 0.673.$$

For potassium:

$$A_s = 1.02 \cdot 10^9 \text{ or } 0.02 \cdot 1.02 \cdot 10^9 \text{ (corrected),}$$

$$t/T = 24/12.44 = 1.93, \text{ which corresponds to } (1 - \exp[-0.693 \cdot t/T]) = 0.740.$$

Neglecting the decay factor in equation (4), we have for the ratio of activities:

$$\frac{A_{\text{Na}}}{A_{\text{K}}} = \frac{0.05 \cdot 1.39 \cdot 10^{10} \cdot 0.673}{0.02 \cdot 1.02 \cdot 10^9 \cdot 0.740} = 31.0.$$

If the irradiation time in this example had been two weeks instead of 1 day, both nuclides would reach saturation activity, and the ratio would be simply that of their corrected  $A_s$  values. Thus

$$\frac{A_{\text{Na}}}{A_{\text{K}}} = \frac{0.05 \cdot 1.39 \cdot 10^{10}}{0.02 \cdot 1.02 \cdot 10^9} = 34.0.$$

## Conclusion.

The method of calculation described is useful for the types of work of which examples are given. It is also useful in making rapid comparison of the activities that might be expected from several different elements. For instance, suppose it is desired to know which of the three elements, cobalt, nickel, or vanadium is, under similar conditions, activated to the greatest extent by thermal neutrons. If reference is made to a cross-section table only, the values may be misleading unless properly interpreted by a suitable comparison of half-lives and abundances. In this table all the variables have been combined and the desired information can be obtained directly from the values of  $A_s\lambda$ , the activity produced per gram per second of irradiation, under the stated conditions. Hence, it is easily seen that, under similar circumstances of irradiation, vanadium is most easily activated even though the cross section of one of the cobalt isotopes is nearly five times that of vanadium and the cross section of one of the nickel isotopes is three times that of vanadium.

\* \* \*

The authors wish to express their appreciation to Dr. K. WAY and members of the Nuclear Data Group, National Research Council for making the latest data available. They also wish to thank Professor B. T. FELD of the Massachusetts Institute of Technology for his suggestions and review of the manuscript.

This work is part of a program undertaken by the U. S. Geological Survey on behalf of the Division of Research of the U.S. Atomic Energy Commission.

TABLE I. Nuclides Produced by Thermal Neutrons. (n, p) and (n,  $\alpha$ ) reactions.

TARGET NUCLIDE				PRODUCT NUCLIDE						
Atomic number	Symbol	Mass number	Relative percent abundance	Cross-section for 2200 m/s neutrons (10 <sup>-24</sup> cm <sup>2</sup> -barn)	Symbol	Half-life	Decay constant (s <sup>-1</sup> )	Specific saturation activity (°) (disint./s/g)	Activity after 1s irradiation (°) (disint./s/g)	NOTES
Z		A	k	σ		T	λ	A <sub>s</sub>	A <sub>g</sub> <sup>λ</sup>	
2	He	3	1.3·10 <sup>-4</sup> atmospheric	5.2·10 <sup>3</sup> (a)	<sup>3</sup> H	12.46	a	1.763·10 <sup>-9</sup>	1.36·10 <sup>-9</sup>	β <sup>-</sup> , no γ
3	Li	6	7.52	9.3·10 <sup>2</sup> (b)	<sup>3</sup> H	12.46	a	1.763·10 <sup>-9</sup>	1.2·10 <sup>4</sup>	β <sup>-</sup> , no γ
5	B	10	18.8	<0.2 (a) 3.990·10 <sup>3</sup> (b)	<sup>10</sup> Be <sup>7</sup> Li	2.5·10 <sup>6</sup> stable	8.8·10 <sup>-15</sup> —	<2.3·10 <sup>9</sup> —	<2·10 <sup>-5</sup> —	β <sup>-</sup> , no γ —
7	N	14	99.635	1.70 (a)	<sup>14</sup> C	5.568·10 <sup>3</sup> a	3.945·10 <sup>-12</sup>	7.30·10 <sup>10</sup>	0.29	β <sup>-</sup> , no γ
8	O	17	3.7·10 <sup>-2</sup> air	0.5 (b)	<sup>14</sup> C	5.568·10 <sup>3</sup> a	3.945·10 <sup>-12</sup>	6.5·10 <sup>6</sup>	2.6·10 <sup>-5</sup>	β <sup>-</sup> , no γ
16	S	33	0.750 meteoritic	2.3·10 <sup>-3</sup> (a)	<sup>33</sup> P	25.4	d	3.16·10 <sup>-7</sup>	9.3·10 <sup>-2</sup>	β <sup>-</sup> , no γ
17	Cl	35	75.4	0.17 (a)	<sup>35</sup> S	87.1	d	9.21·10 <sup>-8</sup>	2.0·10 <sup>2</sup>	β <sup>-</sup>
26	Fe	54	5.84	1.1·10 <sup>-2</sup> (a)	<sup>54</sup> Mn	3.10·10 <sup>2</sup> d	2.59·10 <sup>-8</sup>	7.16·10 <sup>6</sup>	0.18	γ, EC, no β <sup>-</sup> , no β <sup>+</sup>

(a) (n, p) reaction.

(b) (n,  $\alpha$ ) reaction.(°)  $A_s$  and  $A_g^{\lambda}$  are based on neutron flux of 10<sup>12</sup> neutrons/cm<sup>2</sup> s, and 1 gram of element.



TABLE II. Nuclides Produced by Thermal Neutrons. ( $n, \gamma$ ) reactions.

TARGET NUCLIDE					PRODUCT NUCLIDE					NOTES
Atomic number	Symbol	Mass number	Relative percent abundance	Cross-section for 2200 m/s neutrons ( $10^{-24}\text{cm}^2\text{-barn}$ )	Symbol	Half-life	Decay constant ( $\text{s}^{-1}$ )	Specific saturation activity ( $^{(b)}$ ) (disint./s/g)	Activity after 1s irradiation ( $^{(b)}$ ) (disint./s/g)	
Z		A	k	$\sigma$		T	$\lambda$	$A_s$	$A_{s1}$	
1	H	2	$1.4 \cdot 10^{-2}$	$5.7 \cdot 10^{-4}$	$^3\text{H}$	12.46 a	$1.763 \cdot 10^{-9}$	$2.40 \cdot 10^4$	$4.2 \cdot 10^{-5}$	$\beta^-$ , no $\gamma$
3	Li	6	7.52	0.1	$^7\text{Li}^m$	$5.2 \cdot 10^{-14}$ s	$1.3 \cdot 10^{13}$	$7.5 \cdot 10^8$	$^{(b)}$	IT
		7	92.48	$3.3 \cdot 10^{-2}$	$^8\text{Li}$	0.825 s	0.840	$2.63 \cdot 10^9$	$^{(b)}$	$2\alpha$ , $\beta^-$ , no $\gamma$
4	Be	9	100	$1 \cdot 10^{-2}$	$^{10}\text{Be}$	$2.5 \cdot 10^6$ a	$8.8 \cdot 10^{-15}$	$6.7 \cdot 10^8$	$5.8 \cdot 10^{-6}$	$\beta^-$ , no $\gamma$
5	B	11	81.2	$< 5.0 \cdot 10^{-2}$	$^{12}\text{B}$	$2.7 \cdot 10^{-2}$ s	26	$< 2.2 \cdot 10^9$	$^{(b)}$	$\beta^-$ , $\gamma$
6	C	13	1.108	$\leq 1 \cdot 10^{-2}$	$^{14}\text{C}$	$5.568 \cdot 10^3$ a	$3.945 \cdot 10^{-12}$	$\leq 5$	$\leq 2 \cdot 10^{-5}$	$\beta^-$ , no $\gamma$
		14	art. $^{(c)}$	$< 10^{-6}$ $^{(d)}$	$^{15}\text{C}$	2.4 s	0.29	$< 4.3 \cdot 10^4$ $^{(e)}$	$< 10^4$	$\beta^-$ , $\gamma$
7	N	14	99.635	0.1	$^{15}\text{N}$	stable	—	—	—	—
		15	0.365	$2.4 \cdot 10^{-5}$	$^{16}\text{N}$	7.35 s	$9.43 \cdot 10^{-2}$	$3.5 \cdot 10^3$	$3.3 \cdot 10^2$	$\beta^-$ , $\gamma$
8	O	18	$0.204_{\text{air}}$	$2.1 \cdot 10^{-4}$	$^{19}\text{O}$	29.4 s	$2.36 \cdot 10^{-2}$	$1.43 \cdot 10^4$	$3.4 \cdot 10^2$	$\beta^-$ , $\gamma$
9	F	19	100	$9 \cdot 10^{-3}$	$^{20}\text{F}$	10.7 s	$6.48 \cdot 10^{-2}$	$2.8 \cdot 10^8$	$2 \cdot 10^7$	$\beta^-$ , $\gamma$
10	Ne	22	8.82	$3.6 \cdot 10^{-2}$	$^{23}\text{Ne}$	40.2 s	$1.72 \cdot 10^{-2}$	$8.69 \cdot 10^7$	$1.5 \cdot 10^6$	$\beta^-$ , $\gamma$
11	Na	23	100	0.53	$^{24}\text{Na}$	15.06 h	$1.278 \cdot 10^{-5}$	$1.39 \cdot 10^{10}$	$1.78 \cdot 10^5$	$\beta^-$ , $\gamma$
12	Mg	24	78.60	$3.3 \cdot 10^{-2}$	$^{25}\text{Mg}$	stable	—	—	—	—
		25	10.11	0.270	$^{26}\text{Mg}$	stable	—	—	—	—
		26	11.29	$5 \cdot 10^{-2}$	$^{27}\text{Mg}$	9.45 m	$1.22 \cdot 10^{-3}$	$1.3 \cdot 10^8$	$2 \cdot 10^5$	$\beta^-$ , $\gamma$

15	P	29	4.68	0.27	<sup>30</sup> Si	stable	2.62	h	$7.35 \cdot 10^{-5}$	$6.74 \cdot 10^7$	$50$	$\beta^-, \gamma$ (?)
		30	3.05	0.110	<sup>31</sup> Si							
16		31	100	0.19	<sup>32</sup> P		14.30	d	$5.610 \cdot 10^{-7}$	$3.69 \cdot 10^9$	$2.1 \cdot 10^3$	$\beta^-, \text{no } \gamma$
	S	34	4.215 meteoritic	0.26	<sup>35</sup> S		87.1	d	$9.21 \cdot 10^{-8}$	$1.94 \cdot 10^8$	18	$\beta^-$
		36	$1.7 \cdot 10^{-2}$ meteoritic	0.14	<sup>37</sup> S		5.04	m	$2.29 \cdot 10^{-3}$	$3.98 \cdot 10^5$	$9.1 \cdot 10^2$	$\beta^-, \gamma$
17		35	75.4	40	<sup>36</sup> Cl		$4.4 \cdot 10^5$	a	$5.0 \cdot 10^{-14}$	$5.19 \cdot 10^{11}$	$2.6 \cdot 10^{-2}$	$\beta^-, \text{no } \gamma$
	Cl	37	24.6	0.56	<sup>38</sup> Cl		37.29	m	$3.098 \cdot 10^{-4}$	$2.2 \cdot 10^9$	$7 \cdot 10^5$	$\beta^-, \gamma$
18		36	0.337	6	<sup>37</sup> A		35.0	d	$2.29 \cdot 10^{-7}$	$3.4 \cdot 10^8$	80	EC, no $\gamma$
	A	38	$6.3 \cdot 10^{-2}$	0.8	<sup>39</sup> A		$\sim 2.65 \cdot 10^2$	a	$8.29 \cdot 10^{-11}$	$8.0 \cdot 10^6$	$\sim 7 \cdot 10^{-4}$	$\beta^-$
		40	99.600	0.53	<sup>41</sup> A		1.82	h	$1.06 \cdot 10^{-4}$	$7.95 \cdot 10^9$	$8.4 \cdot 10^5$	$\beta^-, \gamma, ^{41}\text{K}^m$
		41	art. (c')	$6 \cdot 10^{-2}$ (d)	<sup>42</sup> A		$> 3.5$	a	$< 6.3 \cdot 10^{-9}$	$8.8 \cdot 10^8$ (c)	$< 6$	$\beta^-, ^{42}\text{K}$
19		39	93.08	3	<sup>40</sup> K		$1.29 \cdot 10^9$	a	$1.70 \cdot 10^{-17}$	$4.31 \cdot 10^{10}$	$7.33 \cdot 10^{-7}$	$\beta^-, \gamma, \text{EC}$
	K	40	$1.19 \cdot 10^{-2}$	70	<sup>41</sup> K		stable		—	—	—	—
		41	6.91	1.0	<sup>42</sup> K		12.44	h	$1.548 \cdot 10^{-5}$	$1.02 \cdot 10^9$	$1.5 \cdot 10^4$	$\beta^-, \gamma$
20		40	96.97	$< 10^{-4}$	<sup>41</sup> Ca		$1.1 \cdot 10^5$	a	$2.0 \cdot 10^{-13}$	$< 1.5 \cdot 10^6$	$< 3.0 \cdot 10^{-7}$	EC
	Ca	42	0.64	40	<sup>43</sup> Ca		stable		—	—	—	—
		44	2.06	0.63	<sup>45</sup> Ca		$1.52 \cdot 10^2$	d	$5.28 \cdot 10^{-8}$	$1.78 \cdot 10^8$	9.4	$\beta^-, \text{no } \gamma$
		46	$3.3 \cdot 10^{-3}$	0.25	<sup>47</sup> Ca		4.8	d	$1.7 \cdot 10^{-6}$	$1.08 \cdot 10^5$	0.18	$\beta^-, \gamma, ^{47}\text{Sc}$
		48	0.185	1.1	<sup>49</sup> Ca		8.5	m	$1.4 \cdot 10^{-3}$	$2.54 \cdot 10^7$	$3.6 \cdot 10^4$	$\beta^-, \gamma$

(a)  $A_s$  and  $A_s \lambda$  are based on neutron flux of  $10^{12}$  neutrons/cm<sup>2</sup> s, and 1 gram of element.(b)  $1 \text{ s} \geq 0.15 \cdot T$ .

(c) Second order reaction.

(c) Calculation of  $A_s$  based on

100 % abundance of parent nuclide.

(c) Prefix «art.» indicates artificial nuclide.

TABLE II (continued).

TARGET NUCLIDE					PRODUCT NUCLIDE					
Atomic number	Symbol	Mass number	Relative percent abundance	Cross-section for 2200 m/s neutrons ( $10^{-24}$ cm <sup>2</sup> -barn)	Symbol	Half-life	Decay constant ( $s^{-1}$ )	Specific saturation activity ( $\mu$ ) (disint./s g)	Activity after 1s irradiation ( $\mu$ ) (disint./s g)	NOTES
<i>Z</i>		<i>A</i>	<i>k</i>	$\sigma$		<i>T</i>	$\lambda$	$A_s$	$A_s \lambda$	
21	Sc	45	100	13	<sup>45</sup> Sc <sup>m</sup>	19.5 s	$3.56 \cdot 10^{-2}$	$1.74 \cdot 10^{11}$	$6.2 \cdot 10^9$	IT, <sup>46</sup> Sc
					<sup>46</sup> Sc	85 d	$9.4 \cdot 10^{-8}$	$1.60 \cdot 10^{11}$	$1.5 \cdot 10^4$	$\beta^-$ , $\gamma$
22	Ti	46	7.95	0.57	<sup>47</sup> Ti	stable	—	—	—	—
					<sup>48</sup> Ti	stable	—	—	—	—
					<sup>49</sup> Ti	stable	—	—	—	—
					<sup>50</sup> Ti	stable	—	—	—	—
					<sup>51</sup> Ti	5.82 m	$1.98 \cdot 10^{-3}$	$9.01 \cdot 10^7$	$1.8 \cdot 10^5$	$\beta^-$ , $\gamma$
23	V	51	99.76	4.5	<sup>52</sup> V <sup>m(t)</sup>	3.76 m	$3.07 \cdot 10^{-3}$	$5.30 \cdot 10^{10}$	$1.6 \cdot 10^8$	$\beta^-$ , IT
24	Cr	50	4.31	11	<sup>51</sup> Cr	27.8 d	$2.89 \cdot 10^{-7}$	$5.71 \cdot 10^9$	$1.7 \cdot 10^3$	$\gamma$ , EC, no $\beta^+$
					<sup>53</sup> Cr	stable	—	—	—	—
					<sup>54</sup> Cr	stable	—	—	—	—
					<sup>55</sup> Cr	~2 h	$\sim 10^{-4}$	$< 7.9 \cdot 10^7$	$\sim 8 \cdot 10^3$	—
25	Mn	55	100	12.7	<sup>56</sup> Mn	2.576 h	$7.474 \cdot 10^{-5}$	$1.390 \cdot 10^{11}$	$1.03 \cdot 10^7$	$\beta^-$ , $\gamma$
26	Fe	54	5.84	0.7	<sup>55</sup> Fe	2.94 a	$7.74 \cdot 10^{-9}$	$4.56 \cdot 10^8$	4	EC, no $\beta^+$ or $\gamma$
					<sup>57</sup> Fe	stable	—	—	—	—
					<sup>58</sup> Fe	stable	—	—	—	—

	60m	art. (c')	20	<sup>60</sup> Co	5.27	a	$4.17 \cdot 10^{-9}$	$2.04 \cdot 10^{11}$	$8.5 \cdot 10^2$	$\beta^-$ , $\gamma$
	60	art. (c')	6	<sup>61</sup> Co	99.0	m	$1.2 \cdot 10^{-4}$	$1.0 \cdot 10^{12(c)}$	$1.2 \cdot 10^8$	$\beta^-$ , $\gamma$ (weak)
				<sup>61</sup> Co	99.0	m	$1.2 \cdot 10^{-4}$	$1.0 \cdot 10^{12(c)}$	1	$\beta^-$ , $\gamma$ (weak)
28	Ni	67.76	4.2	<sup>59</sup> Ni	8	$10^4$ a	$2.7 \cdot 10^{-13}$	$2.95 \cdot 10^{10}$	$8.0 \cdot 10^{-8}$	EC, no $\gamma$
	60	26.16	2.7	<sup>61</sup> Ni	stable		—	—	—	—
	61	1.25	1.8	<sup>62</sup> Ni	stable		—	—	—	—
	62	3.66	15	<sup>63</sup> Ni	85	a	$2.6 \cdot 10^{-10}$	$5.33 \cdot 10^9$	1.38	$\beta^-$
	64	1.16	2.6	<sup>65</sup> Ni	2.564	h	$7.509 \cdot 10^{-5}$	$2.84 \cdot 10^8$	$2.1 \cdot 10^4$	$\beta^-$ , $\gamma$
	65	art. (c')	6	<sup>66</sup> Ni	56	h	$3.4 \cdot 10^{-6}$	$5.6 \cdot 10^{10(c)}$	2	$\beta^-$ , <sup>66</sup> Cu
29	Cu	69.1	4.0	<sup>64</sup> Cu	12.80	h	$1.504 \cdot 10^{-5}$	$2.6 \cdot 10^4$	4	$\beta^-$ , $\beta^+$ , $\gamma$ , EC
	65	30.9	2.0	<sup>66</sup> Cu	5.10	m	$2.27 \cdot 10^{-3}$	$5.7 \cdot 10^9$	1	$\beta^-$ , $\gamma$
30	Zn	48.89	0.5	<sup>65</sup> Zn	$2.5 \cdot 10^2$	d	$2.3 \cdot 10^{-8}$	$2.3 \cdot 10^9$	53	$\beta^+$ , EC
	68	18.56	0.10	<sup>69</sup> Zn <sup>m</sup>	13.8	h	$1.40 \cdot 10^{-5}$	$1.6 \cdot 10^8$	2	IT, <sup>69</sup> Zn
			1.0	<sup>69</sup> Zn	52	m	$2.2 \cdot 10^{-4}$	$1.6 \cdot 10^9$	4	$\beta^-$ , no $\gamma$
	70	0.62	$8.5 \cdot 10^{-2}$	<sup>71</sup> Zn	2.2	m	$5.3 \cdot 10^{-3}$	$4.53 \cdot 10^6$	$2.4 \cdot 10^4$	$\beta^-$
31	Ga	60.2	1.4	<sup>70</sup> Ga	20.3	m	$5.69 \cdot 10^{-4}$	$7.33 \cdot 10^9$	$4.2 \cdot 10^6$	$\beta^-$
	71	39.8	3.4	<sup>72</sup> Ga	14.1	h	$1.37 \cdot 10^{-5}$	$1.15 \cdot 10^{10}$	$1.6 \cdot 10^5$	$\beta^-$ , $\gamma$ , <sup>72</sup> Ge <sup>m</sup>

(<sup>a</sup>)  $A_s$  and  $A_s \lambda$  are based on neutron flux of  $10^{12}$  neutrons/cm<sup>2</sup>s, and 1 gram of element. (<sup>c</sup>) Calculation of  $A_s$  based on 100 % abundance of parent nuclide. (<sup>c'</sup>) Prefix = art., indicates artificial nuclide. (<sup>d</sup>) Second order reaction.



TABLE II (continued).

TARGET NUCLIDE				PRODUCT NUCLIDE							
Atomic number	Symbol	Mass number	Relative percent abundance	Cross-section for 2200 m/s neutrons (10 <sup>-24</sup> cm <sup>2</sup> -barn)	Symbol	Half-life	Decay constant (s <sup>-1</sup> )	Specific saturation activity (disint./s g)	Activity after 1s irradiation (disint./s g)	NOTES	
Z		A	k	σ		T	λ	A <sub>s</sub>	A <sub>s</sub> λ		
32	Ge	70	20.55	3.3	<sup>71</sup> Ge	11.4 d	7.04 · 10 <sup>-7</sup>	5.83 · 10 <sup>9</sup>	4.1 · 10 <sup>3</sup>	EC, no β <sup>+</sup> , no γ	
		72	27.37	0.94	<sup>73</sup> Ge	stable	—	—	—	—	—
		73	7.67	13.7	<sup>74</sup> Ge	stable	—	—	—	—	—
		74	36.74	0.45	<sup>75</sup> Ge	82 m	1.4 · 10 <sup>-4</sup>	1.34 · 10 <sup>9</sup>	1.9 · 10 <sup>5</sup>	1.9 · 10 <sup>5</sup>	β <sup>-</sup> , γ
		76	7.67	3.0 · 10 <sup>-2</sup>	<sup>77</sup> Ge <sup>m</sup> ↓ <sup>77</sup> Ge	57 s 12 h	1.2 · 10 <sup>-2</sup> 1.6 · 10 <sup>-5</sup>	1.82 · 10 <sup>7</sup> 1.2 · 10 <sup>8</sup>	2 · 10 <sup>5</sup> 2 · 10 <sup>3</sup>	2 · 10 <sup>5</sup> 2 · 10 <sup>3</sup>	β <sup>-</sup> , IT, <sup>77</sup> Ge, <sup>77</sup> As β <sup>-</sup> , γ, <sup>77</sup> As
33	As	75	100	4.1	<sup>76</sup> As	26.1 h	7.38 · 10 <sup>-6</sup>	3.29 · 10 <sup>10</sup>	2.4 · 10 <sup>5</sup>	β <sup>-</sup> , γ	
		34	Se	74	0.87	24	<sup>75</sup> Se	128 d	6.27 · 10 <sup>-8</sup>	1.70 · 10 <sup>9</sup>	1.1 · 10 <sup>2</sup>
76	9.02			7	<sup>77</sup> Se <sup>m</sup>	17.5 s	3.96 · 10 <sup>-2</sup>	5.0 · 10 <sup>9</sup>	2 · 10 <sup>8</sup>	2 · 10 <sup>8</sup>	IT
77	7.58			40	<sup>78</sup> Se	sable	—	—	—	—	—
78	23.52			0.4	<sup>79</sup> Se	stable	—	—	—	—	—
80	49.82			3 · 10 <sup>-2</sup>	<sup>81</sup> Se <sup>m</sup> ↓ <sup>81</sup> Se	56.5 m 17 m	2.05 · 10 <sup>-4</sup> 6.8 · 10 <sup>-4</sup>	1.1 · 10 <sup>8</sup> 1.9 · 10 <sup>9</sup>	2.2 · 10 <sup>4</sup> 1 · 10 <sup>6</sup>	2.2 · 10 <sup>4</sup> 1 · 10 <sup>6</sup>	IT, <sup>81</sup> Se β <sup>-</sup> , no γ
35	Br	82	9.19	5 · 10 <sup>-2</sup>	<sup>83</sup> Se	67 s	1.0 · 10 <sup>-2</sup>	3.4 · 10 <sup>7</sup>	3.4 · 10 <sup>5</sup>	β <sup>-</sup> , <sup>83</sup> Br	
				4 · 10 <sup>-3</sup>	<sup>83</sup> Se	25 m	4.7 · 10 <sup>-4</sup>	2.7 · 10 <sup>6</sup>	1 · 10 <sup>3</sup>	1 · 10 <sup>3</sup>	β <sup>-</sup> , γ, <sup>83</sup> Br
35	Br	79	50.52	2.9	<sup>80</sup> Br <sup>m</sup> ↓ <sup>80</sup> Br	4.58 h 18 m	4.20 · 10 <sup>-5</sup> 6.4 · 10 <sup>-4</sup>	1.12 · 10 <sup>10</sup> 3.27 · 10 <sup>10</sup>	4.7 · 10 <sup>5</sup> 2.1 · 10 <sup>7</sup>	IT, <sup>80</sup> Br β <sup>-</sup> , β <sup>+</sup> , EC	
				8.5							



TABLE II (continued).

TARGET NUCLIDE				PRODUCT NUCLIDE						
Atomic number	Symbol	Mass number	Relative percent abundance	Cross-section for 2200 m/s neutrons ( $10^{-24}\text{cm}^2\text{-barn}$ )	Symbol	Half-life	Decay constant ( $\text{s}^{-1}$ )	Specific saturation activity ( $^{(d)}$ ) (disint./s g)	Activity after 1s irradiation ( $^{(d)}$ ) (disint./s g)	NOTES
Z	A		k	$\sigma$		$T_{1/2}$	$\lambda$	$A_s$	$A_s^1$	
41	Nb	93	100	1.1	$^{94}\text{Nb}^m$	6.6	$1.8 \cdot 10^{-3}$	$7.13 \cdot 10^9$	$1.3 \cdot 10^7$	IT, $^{94}\text{Nb}$
		94	art. $^{(d)}$	15	$^{95}\text{Nb}$	35	$2.3 \cdot 10^{-7}$	$9.61 \cdot 10^{10(d)}$	$2.2 \cdot 10^4$	$\beta^-$ , $\gamma$
42	Mo	92	15.86	$< 6 \cdot 10^{-3}$	$^{93}\text{Mo}^m$	6.95	$2.77 \cdot 10^{-5}$	$6.2 \cdot 10^6$	$2 \cdot 10^2$	IT
		95	15.70	13.4	$^{96}\text{Mo}$	stable	—	—	—	—
		96	16.50	1.2	$^{97}\text{Mo}$	stable	—	—	—	—
		97	9.45	2.1	$^{98}\text{Mo}$	stable	—	—	—	—
		98	23.75	0.13	$^{99}\text{Mo}$	67	$2.87 \cdot 10^{-6}$	$1.90 \cdot 10^8$	$5.4 \cdot 10^2$	$\beta^-$ , $\gamma$ , $^{99}\text{Tc}^m$ , $^{99}\text{Tc}$
		100	9.62	0.20	$^{101}\text{Mo}$	14.6	$7.91 \cdot 10^{-4}$	$1.2 \cdot 10^8$	$9.5 \cdot 10^4$	$\beta^-$ , $\gamma$ , $^{101}\text{Tc}$
					$^{97}\text{Ru}$	2.8	$2.9 \cdot 10^{-6}$	$3.6 \cdot 10^6$	10	EC, $^{97}\text{Tc}^m$
44	Ru	102	31.3	1.2	$^{103}\text{Ru}$	39.8	$2.02 \cdot 10^{-7}$	$2.22 \cdot 10^9$	$4.5 \cdot 10^2$	$\beta^-$ , $\gamma$ , $^{103}\text{Rh}^m$
		104	18.3	0.7	$^{105}\text{Ru}$	4.5	$4.3 \cdot 10^{-5}$	$7.4 \cdot 10^8$	$3 \cdot 10^4$	$\beta^-$ , $\gamma$ , $^{105}\text{Rh}$ , $^{105}\text{Rh}^m$
		103	100	12	$^{104}\text{Rh}^m$	4.4	$2.6 \cdot 10^{-3}$	$7.02 \cdot 10^{10}$	$1.8 \cdot 10^8$	IT, $^{104}\text{Rh}$
45	Rh			$1.37 \cdot 10^2$	$^{104}\text{Rh}$	44	$1.6 \cdot 10^{-2}$	$8.010 \cdot 10^{11}$	$1.3 \cdot 10^{10}$	$\beta^-$ , $\gamma$
46	Pd	102	0.8	4.8	$^{103}\text{Pd}$	17.0	$4.72 \cdot 10^{-7}$	$2.27 \cdot 10^{10}$	$1.1 \cdot 10^4$	EC, $^{103}\text{Rh}^m$ , $^{103}\text{Rh}$
		108	26.8	7.7	$^{109}\text{Pd}$	13.6	$1.42 \cdot 10^{-5}$	$1.15 \cdot 10^{10}$	$1.6 \cdot 10^5$	$\beta^-$ , $^{109}\text{Ag}^m$ , $^{109}\text{Ag}$
		110	13.5	0.4	$^{111}\text{Pd}$	22	$5.3 \cdot 10^{-4}$	$2.9 \cdot 10^8$	$1.5 \cdot 10^5$	$\beta^-$ , $\gamma$ , $^{111}\text{Ag}$
47	Ag	107	51.35	32	$^{108}\text{Ag}$	2.3	$5.0 \cdot 10^{-3}$	$9.25 \cdot 10^{-10}$	$4.6 \cdot 10^8$	$\beta^-$ , $\gamma$ , EC
		109	48.65	2.2	$^{110}\text{Ag}^m$	$2.7 \cdot 10^2$	$2.07 \cdot 10^{-8}$	$5.01 \cdot 10^8$	$2 \cdot 10^2$	$\beta^-$ , $\gamma$ , $^{110}\text{Cd}$

110	12.39	0.2	$^{111}\text{Cd}^{m_2}$	48.6	m	$2.38 \cdot 10^{-4}$	$1.4 \cdot 10^5$	$3 \cdot 10^4$	IT, $^{111}\text{Cd}^{m_1}$
112	24.07	$2 \cdot 10^{-2}$	$^{113}\text{Cd}^{m_2}$	5.1	a	$4.3 \cdot 10^{-9}$	$2.6 \cdot 10^7$	0.1	$\beta^-$
113	12.26	$1.95 \cdot 10^4$ (e)	$^{114}\text{Cd}$	stable					
114	28.86	0.14	$^{115}\text{Cd}^{m_2}$	43	d	$1.9 \cdot 10^{-7}$	$2.14 \cdot 10^8$	41	$\beta^-$ , $\gamma$
		1.1	$^{115}\text{Cd}$	53	h	$3.6 \cdot 10^{-6}$	$1.68 \cdot 10^9$	$6.0 \cdot 10^3$	$\beta^-$ , $\gamma$ , $^{115}\text{In}^{m_2}$
116	7.58	1.4	$^{117}\text{Cd}^{m_2}$	3.0	h	$6.4 \cdot 10^{-5}$	$5.51 \cdot 10^8$	$3.5 \cdot 10^4$	IT, $^{117}\text{In}$
49	In		$^{114}\text{In}^{m_2}$	49	d	$1.6 \cdot 10^{-7}$	$1.26 \cdot 10^{10}$	$2.0 \cdot 10^3$	IT, no EC, $^{114}\text{In}$
			$^{114}\text{In}$	72	s	$9.6 \cdot 10^{-3}$	$4 \cdot 10^8$	$4 \cdot 10^8$	$\beta^-$ , EC
			$^{116}\text{In}^{m_2}$	53.93	m	$2.142 \cdot 10^{-4}$	$7.272 \cdot 10^{11}$	$1.56 \cdot 10^8$	$\beta^-$ , $\gamma$
			$^{116}\text{In}$	13	s	$5.3 \cdot 10^{-2}$	$2.61 \cdot 10^{11}$	$1.4 \cdot 10^{10}$	$\beta^-$ , no $\gamma$
50	Sn		$^{113}\text{Sn}$	$1.12 \cdot 10^2$	d	$7.16 \cdot 10^{-8}$	$6.64 \cdot 10^7$	4.8	EC, no $\beta^+$ , $^{113}\text{In}^{m_2}$
			$^{117}\text{Sn}$	stable					
			$^{119}\text{Sn}^{m_2}$	$\sim 2.5 \cdot 10^2$	d	$\sim 3.21 \cdot 10^{-8}$	$1.3 \cdot 10^7$	$\sim 0.4$	IT
			$^{121}\text{Sn}^{m_2}$	$> 4 \cdot 10^2$	d	$< 2.0 \cdot 10^{-8}$	$2 \cdot 10^6$	$< 10^{-2}$	$\beta^-$
			$^{121}\text{Sn}$	27.5	h	$7.00 \cdot 10^{-6}$	$2.15 \cdot 10^8$	$1.6 \cdot 10^{-3}$	$\beta^-$ , $\gamma$ , $\gamma$
			$^{123}\text{Sn}$	39.5	m	$2.93 \cdot 10^{-4}$	$3.72 \cdot 10^7$	$1.1 \cdot 10^8$	$\beta^-$ , $\gamma$
			$^{123}\text{Sn}$	$1.36 \cdot 10^2$	d	$5.90 \cdot 10^{-7}$	$2.0 \cdot 10^5$	0.1	$\beta^-$ , no $\gamma$
			$^{125}\text{Sn}$	9.5	m	$1.2 \cdot 10^{-3}$	$4.36 \cdot 10^7$	$5 \cdot 10^4$	$\beta^-$ , $\gamma$
			$^{125}\text{Sn}$	9.4	d	$8.5 \cdot 10^{-7}$	$1.5 \cdot 10^6$	1	$\beta^-$ , $\gamma$ , $^{125}\text{Sb}$

(<sup>a</sup>)  $A_s$  and  $A_{s^2}$  are based on neutron flux of  $10^{13}$  neutrons/cm<sup>2</sup>s, and 1 gram of element.  
 parent nuclide. (<sup>e'</sup>) Prefix "art." indicates artificial nuclide. (<sup>e</sup>) Second order reaction. (<sup>c</sup>) Calculation of  $A_s$  based on 100 % abundance of (<sup>e</sup>) Not  $1/\nu \cdot 1.3$ .



TABLE II (continued).

TARGET NUCLIDE				PRODUCT NUCLIDE						
Atomic number	Symbol	Mass number	Relative percent abundance	Cross-section for 2200 m/s neutrons ( $10^{-34}$ cm <sup>2</sup> -barn)	Symbol	Half-life	Decay constant (s <sup>-1</sup> )	Specific saturation activity (disint./s g)	Activity after 1s irradiation (disint./s g)	NOTES
Z		A	k	$\sigma$		T	$\lambda$	$A_s$	$A_{s^1}$	
51	Sb	121	57.25	6.8	<sup>122</sup> Sb	2.80	$2.86 \cdot 10^{-6}$	$1.94 \cdot 10^{10}$	$5.5 \cdot 10^4$	$\beta^-$ , $\gamma$
		123	42.75	$3 \cdot 10^{-2}$	<sup>124</sup> Sb <sub>m<sub>2</sub></sub>	21	$5.5 \cdot 10^{-4}$	$6.3 \cdot 10^7$	$3 \cdot 10^4$	$\beta^-$ , IT, <sup>124</sup> Sb
				$3 \cdot 10^{-2}$	<sup>124</sup> Sb <sub>m<sub>1</sub></sub>	1.3	$8.9 \cdot 10^{-3}$	$6.3 \cdot 10^7$	$6 \cdot 10^5$	$\beta^-$ , IT, <sup>124</sup> Sb
				2.5	<sup>124</sup> Sb	60	$1.3 \cdot 10^{-7}$	$5.23 \cdot 10^9$	$6.8 \cdot 10^2$	$\beta^-$ , $\gamma$ , no $\beta^+$ or EC
52	Te	122	2.46	1.0	<sup>123</sup> Te <sup>m</sup>	$1.04 \cdot 10^2$ d	$7.71 \cdot 10^{-8}$	$1.2 \cdot 10^8$	9	IT
		123	0.87	$3.90 \cdot 10^2$	<sup>124</sup> Te	stable	—	—	—	—
		124	4.61	5	<sup>125</sup> Te <sup>m</sup>	58	$1.4 \cdot 10^{-7}$	$1.1 \cdot 10^9$	$2 \cdot 10^2$	IT
		125	6.99	1.5	<sup>126</sup> Te	stable	—	—	—	—
		126	18.71	$7 \cdot 10^{-2}$	<sup>127</sup> Te <sup>m</sup>	$1.15 \cdot 10^2$ d	$6.98 \cdot 10^{-8}$	$6.3 \cdot 10^7$	4	IT, <sup>127</sup> Te
				0.8	<sup>127</sup> Te	9.3	$2.1 \cdot 10^{-5}$	$7.2 \cdot 10^8$	$2 \cdot 10^4$	$\beta^-$ , no $\gamma$
		128	31.79	$1.5 \cdot 10^{-2}$	<sup>129</sup> Te <sup>m</sup>	33.5	$2.39 \cdot 10^{-7}$	$2.24 \cdot 10^7$	5.3	IT, <sup>129</sup> Te
				0.13	<sup>129</sup> Te	72	$1.6 \cdot 10^{-4}$	$1.94 \cdot 10^8$	$3.1 \cdot 10^4$	$\beta^-$ , $\gamma$
53	I	130	34.49	$< 8 \cdot 10^{-3}$	<sup>131</sup> Te <sup>m</sup>	30	$6.4 \cdot 10^{-6}$	$< 1.3 \cdot 10^7$	$< 80$	IT, <sup>131</sup> Te
				0.22	<sup>131</sup> Te	24.8	$4.66 \cdot 10^{-4}$	$3.52 \cdot 10^8$	$1.6 \cdot 10^5$	$\beta^-$ , $\gamma$ , <sup>131</sup> I
		127	100	6.7	<sup>128</sup> I	24.99	$4.623 \cdot 10^{-4}$	$3.18 \cdot 10^{10}$	$1.5 \cdot 10^7$	$\beta^-$ , $\beta^+$ , $\gamma$ , EC
		129	art. (c')	11	<sup>130</sup> I	12.6	$1.53 \cdot 10^{-5}$	$5.14 \cdot 10^{10}$ (c)	$7.9 \cdot 10^5$	$\beta^-$ , $\gamma$
		131	art. (c')	$6 \cdot 10^2$	<sup>132</sup> I	2.4	$8.0 \cdot 10^{-6}$	$2.8 \cdot 10^{12}$ (c)	$2.2 \cdot 10^7$	$\beta^-$ , $\gamma$

		132	26.89	0.2	<sup>130</sup> Xe	9.2/10	u	1.322·10 <sup>-6</sup>	2.9·10 <sup>7</sup>	4·10 <sup>3</sup>	β <sup>-</sup> , β <sup>+</sup> , γ, EC, IT
		134	10.44	0.2	<sup>135</sup> Xe	9.13	h	2.1·10 <sup>-8</sup>	9.4·10 <sup>7</sup>	2·10 <sup>3</sup>	β <sup>-</sup> , <sup>135</sup> Cs <sup>m</sup> , <sup>135</sup> Cs
		135	art. (c')	3.5·10 <sup>6</sup> (d)	<sup>136</sup> Xe	stable		—	—	—	—
		136	8.87	0.15	<sup>137</sup> Xe	3.9	m	3.0·10 <sup>-3</sup>	5.89·10 <sup>7</sup>	1.8·10 <sup>5</sup>	β <sup>-</sup> , <sup>137</sup> Cs
55	Cs	133	100	1.6·10 <sup>-2</sup>	<sup>134</sup> Cs <sup>m</sup>	3.2	h	6.0·10 <sup>-6</sup>	7.25·10 <sup>7</sup>	4.3·10 <sup>3</sup>	IT, <sup>134</sup> Cs
				26	<sup>134</sup> Cs	2.3	a	9.5·10 <sup>-9</sup>	1.18·10 <sup>11</sup>	1.1·10 <sup>3</sup>	β <sup>-</sup> , γ, no β <sup>+</sup> or EC
		135	art. (c')	15	<sup>136</sup> Cs	13.7	d	5.86·10 <sup>-7</sup>	6.69·10 <sup>10</sup> (c)	3.9·10 <sup>4</sup>	β <sup>-</sup> , γ
		137	art. (c')	< 2	<sup>138</sup> Cs	32.9	m	3.51·10 <sup>-3</sup>	< 8.8·10 <sup>9</sup> (c)	< 3·10 <sup>7</sup>	β <sup>-</sup> , γ
56	Ba	130	0.101	3·10 <sup>-2</sup>	<sup>131</sup> Ba	12.0	d	6.69·10 <sup>-7</sup>	1.4·10 <sup>5</sup>	9·10 <sup>-2</sup>	γ, EC, no β <sup>+</sup> , <sup>131</sup> Cs
		132	9.7·10 <sup>-2</sup>	6	<sup>133</sup> Ba	~ 9.5	a	2.3·10 <sup>-9</sup>	2.7·10 <sup>7</sup>	~ 6·10 <sup>-2</sup>	γ, EC
		134	2.42	2	<sup>135</sup> Ba	stable		—	—	—	—
		135	6.59	5.6	<sup>136</sup> Ba	stable		—	—	—	—
		136	7.81	0.4	<sup>137</sup> Ba	stable		—	—	—	—
		137	11.32	4.9	<sup>138</sup> Ba	stable		—	—	—	—
		138	71.66	0.5	<sup>139</sup> Ba	85.0	m	1.36·10 <sup>-4</sup>	1.6·10 <sup>9</sup>	2·10 <sup>5</sup>	β <sup>-</sup> , γ
		139	art. (c')	4 (d)	<sup>140</sup> Ba	12.80	d	6.27·10 <sup>-7</sup>	1.7·10 <sup>10</sup> (c)	1·10 <sup>4</sup>	β <sup>-</sup> , γ, <sup>140</sup> La
					<sup>140</sup> La	40.0	h	4.81·10 <sup>-6</sup>	3.64·10 <sup>10</sup>	1.7·10 <sup>5</sup>	β <sup>-</sup> , γ
		140	art. (c')	3 (d)	<sup>141</sup> La	3.7	h	5.2·10 <sup>-5</sup>	1.29·10 <sup>10</sup> (c)	6.7·10 <sup>5</sup>	β <sup>-</sup> , γ, <sup>141</sup> Ce

(<sup>a</sup>)  $A_s$  and  $A_s^2$  are based on neutron flux of  $10^{12}$  neutrons/cm<sup>2</sup> s, and 1 gram of element.  
 parent nuclide. (c') Prefix «art.» indicates artificial nuclide. (d) Second order reaction.

(c) Calculation of  $A_s$  based on 100 % abundance of

TABLE II (continued).

T A R G E T N U C L I D E				P R O D U C T N U C L I D E						
Atomic number	Symbol	Mass number	Relative percent abundance	Cross-section for 2200 m/s neutrons (10 <sup>-24</sup> cm <sup>2</sup> -barn)	Symbol	Half-life	Decay constant (s <sup>-1</sup> )	Specific saturation activity (disint./g)	Activity after 1s irradiation (disint./g)	N O T E S
Z		A	k	$\sigma$	T	$\lambda$		$A_s$	$A_{s,1}$	
58	Ce	138	0.250	< 0.4	<sup>139</sup> Ce	1.4 · 10 <sup>2</sup> d	5.7 · 10 <sup>-8</sup>	< 4.4 · 10 <sup>6</sup>	< 0.25	EC
		140	88.48	0.27	<sup>141</sup> Ce	33.1 d	2.42 · 10 <sup>-7</sup>	1.03 · 10 <sup>9</sup>	2.5 · 10 <sup>2</sup>	$\beta^-$ , $\gamma$
		142	11.07	0.85	<sup>143</sup> Ce	33 h	5.8 · 10 <sup>-6</sup>	3.99 · 10 <sup>8</sup>	2.3 · 10 <sup>3</sup>	$\beta^-$ , $\gamma$ , <sup>143</sup> Pr
59	Pr	141	100	11.2	<sup>142</sup> Pr	19.2 h	1.00 · 10 <sup>-5</sup>	4.783 · 10 <sup>10</sup>	4.8 · 10 <sup>5</sup>	$\beta^-$ , $\gamma$ , no $\beta^+$ , no EC
60	Nd	142	27.13	18.5	<sup>143</sup> Nd	stable	—	—	—	—
		143	12.20	2.90 · 10 <sup>2</sup>	<sup>144</sup> Nd	stable	—	—	—	—
		144	23.87	4.8	<sup>145</sup> Nd	stable	—	—	—	—
		145	8.30	52	<sup>146</sup> Nd	stable	—	—	—	—
		146	17.18	1.8	<sup>147</sup> Nd	11.3 d	7.10 · 10 <sup>-7</sup>	1.28 · 10 <sup>9</sup>	9.1 · 10 <sup>2</sup>	$\beta^-$ , $\gamma$ , <sup>147</sup> Pm
		148	5.72	3.3	<sup>149</sup> Nd	2.0 h	9.6 · 10 <sup>-4</sup>	7.68 · 10 <sup>8</sup>	7.4 · 10 <sup>5</sup>	$\beta^-$ , $\gamma$ , <sup>149</sup> Pm
61	Pm	147	art. (c')	60	<sup>148</sup> Pm	5.3 d	1.5 · 10 <sup>-6</sup>	2.46 · 10 <sup>11(c)</sup>	4 · 10 <sup>5</sup>	$\beta^-$ , $\gamma$
62	Sm	144	3.16	< 0.25	<sup>145</sup> Sm	4.1 · 10 <sup>2</sup> d	2.0 · 10 <sup>-8</sup>	< 3.3 · 10 <sup>7</sup>	< 0.66	$\gamma$ , EC, <sup>145</sup> Pm
		152	26.63	1.5 · 10 <sup>2</sup>	<sup>153</sup> Sm	47 h	4.1 · 10 <sup>-6</sup>	1.583 · 10 <sup>11</sup>	6.4 · 10 <sup>5</sup>	$\beta^-$ , $\gamma$ , <sup>153</sup> Eu <sup>m</sup>
		154	22.53	5.5	<sup>155</sup> Sm	23.5 m	4.92 · 10 <sup>-4</sup>	4.85 · 10 <sup>9</sup>	2.4 · 10 <sup>6</sup>	$\beta^-$ , $\gamma$ , <sup>155</sup> Eu
64	Gd	152	0.20	< 1.25 · 10 <sup>2</sup>	<sup>153</sup> Gd	2.36 · 10 <sup>2</sup> d	3.40 · 10 <sup>-8</sup>	< 9.906 · 10 <sup>8</sup>	< 34	$\gamma$ , EC, no $\beta^+$
		158	24.87	4	<sup>159</sup> Gd	18.0 h	1.1 · 10 <sup>-5</sup>	3.8 · 10 <sup>9</sup>	4.2 · 10 <sup>4</sup>	$\beta^-$ , $\gamma$

66	Dy	164	28.18	$2.860 \cdot 10^3$	$^{165}\text{Dy}^m$ ↓ $^{165}\text{Dy}$	1.25	m	$9.24 \cdot 10^{-5}$	$2.959 \cdot 10^{12}$	$2.15 \cdot 10^{-3}$	11
				$2.2 \cdot 10^3$		139.2	m	$8.299 \cdot 10^{-5}$	$2.28 \cdot 10^{12}$	$1.9 \cdot 10^8$	$\beta^-, \gamma, ^{165}\text{Dy}$
67	Ho	165	100	64	$^{166}\text{Ho}$	27.3	h	$7.05 \cdot 10^{-6}$	$2.34 \cdot 10^{11}$	$1.7 \cdot 10^6$	$\beta^-, \gamma, ^{166}\text{Er}^m$
68	Er	170	14.88	> 7	$^{171}\text{Er}$	7.5	h	$2.6 \cdot 10^{-5}$	$> 3.7 \cdot 10^9$	$> 1 \cdot 10^5$	$\beta^-, \gamma, ^{171}\text{Tm}^m, ^{171}\text{Tm}$
69	Tm	169	100	$1.25 \cdot 10^2$	$^{170}\text{Tm}$	129	d	$6.22 \cdot 10^{-8}$	$4.455 \cdot 10^{11}$	$2.77 \cdot 10^4$	$\beta^-, \gamma, \text{no } \beta^+, \text{ or EC, } ^{170}\text{Yb}^m$
70	Yb	174	31.84	60	$^{175}\text{Yb}$	102	h	$1.9 \cdot 10^{-6}$	$6.6 \cdot 10^{10}$	$1 \cdot 10^5$	$\beta^-, \gamma$
		176	12.73	5.5	$^{177}\text{Yb}$	1.8	h	$1.1 \cdot 10^{-4}$	$2.39 \cdot 10^9$	$2.6 \cdot 10^5$	$\beta^-, \gamma, ^{177}\text{Lu}^m$
71	Lu	175	97.40	35	$^{176}\text{Lu}^m$	3.67	h	$5.25 \cdot 10^{-5}$	$1.17 \cdot 10^{11}$	$6.1 \cdot 10^6$	$\beta^-, \gamma, \text{no IT, } ^{176}\text{Hf}^m$
		176	2.60	$4 \cdot 10^3$	$^{177}\text{Lu}$	6.8	d	$1.2 \cdot 10^{-6}$	$3.6 \cdot 10^{11}$	$4 \cdot 10^5$	$\beta^-, \gamma$
72	Hf	174	0.18	$\sim 5 \cdot 10^2$	$^{175}\text{Hf}$	70	d	$1.1 \cdot 10^{-7}$	$\sim 3.1 \cdot 10^9$	$\sim 3 \cdot 10^2$	$\gamma, \text{EC}$
		176	5.15	$\sim 15$	$^{177}\text{Hf}$	stable	stable	—	—	—	—
		177	18.39	$\sim 3.5 \cdot 10^2$	$^{178}\text{Hf}$	stable	stable	—	—	—	—
		178	27.08	$\sim 90$	$^{179}\text{Hf}^m$	19	s	$3.6 \cdot 10^{-2}$	$\sim 8.2 \cdot 10^{10}$	$\sim 3 \cdot 10^9$	IT
		179	13.78	$\sim 75$	$^{180}\text{Hf}^m$	5.5	h	$3.5 \cdot 10^{-5}$	$\sim 3.5 \cdot 10^{10}$	$\sim 1 \cdot 10^6$	IT
		180	35.44	10	$^{181}\text{Hf}$	45	d	$1.8 \cdot 10^{-7}$	$1.19 \cdot 10^{10}$	$2 \cdot 10^3$	$\beta^-, ^{181}\text{Ta}^{m2}, ^{181}\text{Ta}^{m1}$
73	Ta	181	100	$2 \cdot 10^{-2}$	$^{182}\text{Ta}^m$	16.5	m	$7.00 \cdot 10^{-4}$	$6.66 \cdot 10^7$	$5 \cdot 10^4$	$\beta^-, \text{IT, } ^{182}\text{Ta}$
				21	$^{182}\text{Ta}$ ↓	111	d	$7.23 \cdot 10^{-8}$	$6.99 \cdot 10^{10}$	$5.0 \cdot 10^3$	$\beta^-, \gamma$
		182	art. (c')	$5.9 \cdot 10^4$ (d)	$^{183}\text{Ta}$	5.2	d	$1.5 \cdot 10^{-6}$	$1.95 \cdot 10^{14}$ (c)	$2.9 \cdot 10^3$	$\beta^-, \gamma$

(a)  $A_s$  and  $A_g$  are based on neutron flux of  $10^{12}$  neutrons/cm<sup>2</sup> s, and 1 gram of element.(c) Calculation of  $A_g$  based on 100 % abundance of parent nuclide.

(d) Second order reaction.

(c') Prefix "art." indicates artificial nuclide.



TABLE II (continued).

TARGET NUCLIDE				PRODUCT NUCLIDE							
Atomic number	Symbol	Mass number	Relative percent abundance	Cross-section for 2200 m/s neutrons (10 <sup>-24</sup> cm <sup>2</sup> =barn)	Symbol	Half-life	Decay constant (s <sup>-1</sup> )	Specific saturation activity (disint./s g)	Activity after 1s irradiation (disint./s g)	NOTES	
Z		A	k	$\sigma$		T	$\lambda$	$A_s$	$A_s \lambda$		
74	W	180	0.135	10	<sup>181</sup> W	1.4 · 10 <sup>2</sup> d	5.73 · 10 <sup>-8</sup>	4.52 · 10 <sup>7</sup>	2.6	$\gamma$ , EC	
		182	26.4	19	<sup>183</sup> W	stable	—	—	—	—	—
		183	14.4	11	<sup>184</sup> W	stable	—	—	—	—	—
		184	30.6	2.0	<sup>185</sup> W	73.2 d	1.10 · 10 <sup>-7</sup>	2.00 · 10 <sup>9</sup>	2.2 · 10 <sup>2</sup>	$\beta^-$ , $\gamma$	
		186	28.4	40	<sup>187</sup> W	24.1 h	7.99 · 10 <sup>-6</sup>	3.7 · 10 <sup>10</sup>	3 · 10 <sup>5</sup>	$\beta^-$ , $\gamma$ , <sup>187</sup> Re <sup>m</sup>	
75	Re	187	art. (c')	90 (d)	<sup>188</sup> W	65 d	1.2 · 10 <sup>-7</sup>	2.9 · 10 <sup>11(c)</sup>	3 · 10 <sup>4</sup>	$\beta^-$ , <sup>188</sup> Re	
		185	37.07	1.01 · 10 <sup>2</sup>	<sup>186</sup> Re	92.8 h	2.07 · 10 <sup>-6</sup>	1.2 · 10 <sup>11</sup>	2 · 10 <sup>5</sup>	$\beta^-$ , $\gamma$ , EC, no $\beta^+$ , <sup>186</sup> Os <sup>m</sup>	
		187	62.93	75	<sup>188</sup> Re	16.9 h	1.14 · 10 <sup>-5</sup>	1.52 · 10 <sup>11</sup>	1.7 · 10 <sup>6</sup>	$\beta^-$ , $\gamma$	
		184	1.8 · 10 <sup>-2</sup>	~20	<sup>185</sup> Os	97 d	8.3 · 10 <sup>-8</sup>	~1.18 · 10 <sup>7</sup>	~1.0	$\gamma$ , EC, no $\beta^+$	
76	Os	190	26.4	8	<sup>191</sup> Os	16.0 d	5.01 · 10 <sup>-7</sup>	6.7 · 10 <sup>9</sup>	3 · 10 <sup>3</sup>	$\beta^-$ , $\gamma$	
		192	41.0	1.6	<sup>193</sup> Os	30.6 h	6.29 · 10 <sup>-6</sup>	2.06 · 10 <sup>9</sup>	1.3 · 10 <sup>4</sup>	$\beta^-$ , $\gamma$ (with <sup>193</sup> Ir <sup>m</sup> )	
		193	art. (c')	190 (d)	<sup>194</sup> Os	~ 7 · 10 <sup>2</sup> d	~1.1 · 10 <sup>-8</sup>	5.9 · 10 <sup>11(c)</sup>	~6 · 10 <sup>3</sup>	$\beta^-$ , <sup>194</sup> Ir	
		191	38.5	2.6 · 10 <sup>2</sup>	<sup>192</sup> Ir <sup>m</sup>	1.42 m	8.14 · 10 <sup>-3</sup>	3.15 · 10 <sup>11</sup>	2.6 · 10 <sup>9</sup>	IT, <sup>192</sup> Ir	
77	Ir			7 · 10 <sup>2</sup>	<sup>192</sup> Ir	74.37 d	1.079 · 10 <sup>-7</sup>	8.5 · 10 <sup>11</sup>	9.2 · 10 <sup>4</sup>	$\beta^-$ , $\gamma$ , EC, no $\beta^+$	
		193	61.5	1.3 · 10 <sup>2</sup>	<sup>194</sup> Ir	19.0 h	1.01 · 10 <sup>-5</sup>	2.49 · 10 <sup>11</sup>	2.5 · 10 <sup>6</sup>	$\beta^-$ , $\gamma$	
		192	0.78	90	<sup>193</sup> Pt <sup>m</sup>	4.33 d	1.9 · 10 <sup>-6</sup>	2.2 · 10 <sup>9</sup>	4 · 10 <sup>3</sup>	EC, IT	
78	Pt	196	25.4	11	<sup>197</sup> Pt	18 h	1.1 · 10 <sup>-5</sup>	2.50 · 10 <sup>8</sup>	0.4 · 10 <sup>3</sup>	—	

	198	art. (c')	$3.5 \cdot 10^4$ (d)	$^{199}\text{Au}$	3.15 d	$2.55 \cdot 10^{-6}$	$1.06 \cdot 10^{14}$ (c)	$2.7 \cdot 10^8$	$\beta^-$ , $\gamma$ , $^{199}\text{Hg}^{m1}$
80	Hg	23.13	<60	$^{201}\text{Hg}$	stable	—	—	—	—
		13.22	<60	$^{202}\text{Hg}$	stable	—	—	—	—
		29.80	3.0	$^{203}\text{Hg}$	47.9 d	$1.67 \cdot 10^{-7}$	$2.66 \cdot 10^9$	$4.4 \cdot 10^2$	$\beta^-$ , $\gamma$
		6.85	0.43	$^{205}\text{Hg}$	5.5 m	$2.1 \cdot 10^{-3}$	$8.69 \cdot 10^7$	$1.8 \cdot 10^5$	$\beta^-$
81	Tl	29.50	8	$^{204}\text{Tl}$	3.5 a	$6.3 \cdot 10^{-9}$	$7.0 \cdot 10^9$	40	$\beta^-$ , EC, no $\gamma$
		70.50	0.5	$^{206}\text{Tl}$	4.19 m	$2.76 \cdot 10^{-3}$	$1.0 \cdot 10^9$	$3 \cdot 10^6$	$\beta^-$ , no $\gamma$
82	Pb	23.6	$2.6 \cdot 10^{-2}$	$^{207}\text{Pb}$	stable	—	—	—	—
		22.6	0.69	$^{208}\text{Pb}$	stable	—	—	—	—
		52.3	$6 \cdot 10^{-4}$	$^{209}\text{Pb}$	3.22 h	$5.98 \cdot 10^{-5}$	$9.1 \cdot 10^5$	50	$\beta^-$ , no $\gamma$
83	Bi	100	$1.7 \cdot 10^{-2}$	$^{210}\text{Bi}$	5.02 d	$1.60 \cdot 10^{-6}$	$4.90 \cdot 10^7$	78	$\alpha$ , $\beta^-$ , no $\gamma$ , $^{206}\text{Tl}$
88	Ra	226	20	$^{227}\text{Ra}$	41.2 m	$2.80 \cdot 10^{-4}$	$5.33 \cdot 10^{10}$ (c)	1.5	$\beta^-$ , $\gamma$ , $^{227}\text{Ac}$
			$\sim 19$ (f)	$^{227}\text{Ac}$	22.0 a	$1.0 \cdot 10^{-9}$	$\sim 5.06 \cdot 10^{10}$ (c)	$\sim 50$	$\alpha$ , $\beta^-$ , $\gamma$ , $^{227}\text{Th}$ , $^{223}\text{Fr}$
		228	$\sim 36$ (f)	$^{229}\text{Ac}$	66 m	$1.8 \cdot 10^{-4}$	$\sim 9.51 \cdot 10^{10}$ (c)	$\sim 1.7 \cdot 10^7$	$\beta^-$
89	Ac	227	$5.6 \cdot 10^2$	$^{228}\text{Ac}$	6.13 h	$3.14 \cdot 10^{-5}$	$1.369 \cdot 10^{12}$ (c)	$4.30 \cdot 10^7$	$\beta^-$ , $\gamma$ , $^{228}\text{Th}$
90	Th	230	35	$^{231}\text{Th}$	25.64 h	$7.509 \cdot 10^{-6}$	$9.17 \cdot 10^{10}$ (c)	$6.9 \cdot 10^5$	$\beta^-$ , $\gamma$ , $^{231}\text{Pa}$
		232	7.6	$^{233}\text{Th}$	23.3 m	$4.96 \cdot 10^{-4}$	$1.97 \cdot 10^{10}$	$9.8 \cdot 10^6$	$\beta^-$ , $\gamma$ (?), $^{233}\text{Pa}$
		233	$1.4 \cdot 10^3$ (d)	$^{234}\text{Th}$	24.10 d	$3.33 \cdot 10^{-7}$	$3.62 \cdot 10^{12}$ (c)	$1.21 \cdot 10^6$	$\beta^-$ , $\gamma$ , $^{234}\text{Pa}$

(a)  $A_s$  and  $A_s^2$  are based on neutron flux of  $10^{13}$  neutrons/cm<sup>2</sup> s, and 1 gram of element.

(c') Prefix "art." indicates artificial nuclide.

(d) Second order reaction.

(e) Calculation of  $A_s$  based 100% abundance of parent nuclide.(f) (n,  $\gamma$ ) reaction.

(g) Abundance unknown.

TABLE II (continued).

T A R G E T   N U C L I D E				P R O D U C T   N U C L I D E						
Atomic number	Symbol	Mass number	Relative percent abundance	Cross-section for 2200 m/s neutrons (10 <sup>-24</sup> cm <sup>2</sup> -barn)	Symbol	Half-life	Decay constant (s <sup>-1</sup> )	Specific saturation activity (disint./g)	Activity after 1s irradiation (disint./g)	N O T E S
Z		A	k	σ		T	λ	A <sub>s</sub>	A <sub>s</sub> <sup>2</sup>	
91	Pa	231		2.6 · 10 <sup>2</sup>	<sup>232</sup> Pa	1.32 d	6.08 · 10 <sup>-6</sup>	6.78 · 10 <sup>11(c)</sup>	4.1 · 10 <sup>6</sup>	β <sup>-</sup> , γ, no EC, <sup>232</sup> U
		232	art. (c')	40 (d)	<sup>233</sup> Pa	27.4 d	2.93 · 10 <sup>-7</sup>	1.04 · 10 <sup>11(c)</sup>	3 · 10 <sup>4</sup>	β <sup>-</sup> , γ, <sup>233</sup> U
92	U	232	art. (c')	3 · 10 <sup>2</sup>	<sup>233</sup> U	1.62 · 10 <sup>5</sup> a	1.35 · 10 <sup>-13</sup>	7.8 · 10 <sup>11(c)</sup>	0.1	α, γ, <sup>229</sup> Th
		234	5.8 · 10 <sup>-3</sup>	75	<sup>235</sup> U	7.13 · 10 <sup>8</sup> a	3.08 · 10 <sup>-17</sup>	1.12 · 10 <sup>7</sup>	3.4 · 10 <sup>-10</sup>	α, γ, <sup>231</sup> Th
		235	0.715	1.07 · 10 <sup>2</sup>	<sup>236</sup> U	2.39 · 10 <sup>7</sup> a	9.19 · 10 <sup>-16</sup>	1.961 · 10 <sup>9</sup>	2 · 10 <sup>-6</sup>	α, γ
		238	99.28	2.75	<sup>239</sup> U	23.54 m	4.908 · 10 <sup>-4</sup>	6.909 · 10 <sup>9</sup>	3.39 · 10 <sup>6</sup>	β <sup>-</sup> , γ, <sup>239</sup> Np
		239	art. (c')	22 (d)	<sup>240</sup> U	≈ 18 h	≈ 1.1 · 10 <sup>-5</sup>	5.54 · 10 <sup>10(c)</sup>	~ 6.1 · 10 <sup>5</sup>	β <sup>-</sup> , <sup>240</sup> Np
93	Np	237		1.7 · 10 <sup>2</sup>	<sup>238</sup> Np	2.10 d	3.82 · 10 <sup>-6</sup>	4.32 · 10 <sup>11(c)</sup>	1.7 · 10 <sup>6</sup>	β <sup>-</sup> , γ, <sup>238</sup> Pu
94	Pu	238	art. (c')	4.25 · 10 <sup>2</sup>	<sup>239</sup> Pu	2.436 · 10 <sup>4</sup> a	9.017 · 10 <sup>-13</sup>	1.1 · 10 <sup>12(c)</sup>	0.992	α, β <sup>-</sup>
		239		3.15 · 10 <sup>2</sup> (d)	<sup>240</sup> Pu	6.58 · 10 <sup>3</sup> a	3.34 · 10 <sup>-12</sup>	7.938 · 10 <sup>11(c)</sup>	2.65	α, β <sup>-</sup>
		241	art. (c')	4 · 10 <sup>2</sup>	<sup>242</sup> Pu	~ 5 · 10 <sup>5</sup> a	~ 4 · 10 <sup>-14</sup>	1.0 · 10 <sup>12(c)</sup>	~ 4 · 10 <sup>-2</sup>	α
		242		40 (d)	<sup>243</sup> Pu	4.98 h	3.87 · 10 <sup>-5</sup>	1.0 · 10 <sup>11(c)</sup>	4 · 10 <sup>6</sup>	β <sup>-</sup> , γ, <sup>243</sup> Am
95	Am	241	art. (c')	7 · 10 <sup>2</sup>	<sup>242</sup> Am <sup>m</sup>	16.01 h	1.203 · 10 <sup>-5</sup>	1.75 · 10 <sup>12(c)</sup>	2.1 · 10 <sup>7</sup>	β <sup>-</sup> , EC, IT, <sup>242</sup> Cm, <sup>242</sup> Pu
			< 50	<sup>242</sup> Am	10 <sup>2</sup>	5.49 · 10 <sup>-11</sup>	> 1.25 · 10 <sup>11</sup>	< 7	α, β <sup>-</sup> , EC, <sup>242</sup> Cm, <sup>238</sup> Np	
		243		50	<sup>244</sup> Am	25 m	4.6 · 10 <sup>-4</sup>	12 · 10 <sup>11(c)</sup>	5.5 · 10 <sup>7</sup>	β <sup>-</sup>

(<sup>a</sup>)  $A_s$  and  $A_s^A$  are based on neutron flux of  $10^{12}$  neutrons/cm<sup>2</sup>s, and 1 gram of element. (<sup>c</sup>) Calculation of  $A_s$  based 100% abundance of parent nuclide. (<sup>c'</sup>) Prefix "art." indicates artificial nuclide. (<sup>d</sup>) Second order reaction.



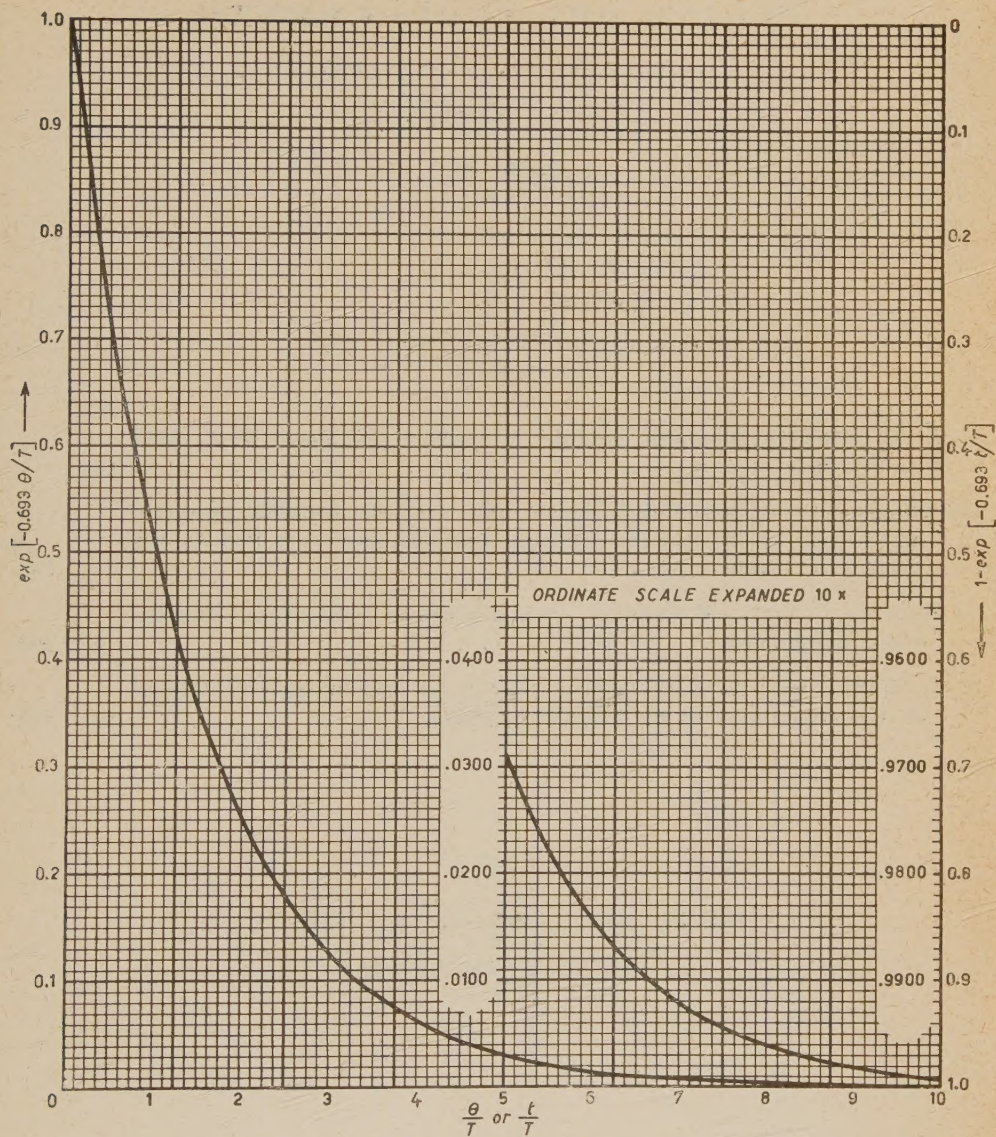


Fig. 1. - Graph of the decay factor,  $\exp[-0.693 \theta/T]$  (on the left), and growth factor,  $1 - \exp[-0.693 t/T]$  (on the right).

# INDICE DEL SUPPLEMENTO

AL VOLUME XII, SERIE IX, DEL

NUOVO CIMENTO

Anno 1954

Atti del XXXIX Congresso tenutosi a Cagliari nei giorni 23-27 Settembre 1953 . . . . .	pag. 1
Rendiconti del Congresso internazionale sulle particelle instabili pesanti e sugli eventi di alta energia nei raggi cosmici, tenutosi a Padova nei giorni 12-15 Aprile 1954 . . . . .	» 163
L. BERETTA, C. VILLI e F. FERRARI - Sezioni d'urto elastico protone-protone e neutrone-protone . . . . .	» 499
F. E. SEFTLE and W. R. CHAMPION - Tables for Simplifying Calculations of Activities Produced by Thermal Neutrons . . . . .	» 549

---

Fine del *Supplemento* al Vol. XII, Serie IX  
del *Nuovo Cimento*, 1954

---

PROPRIETÀ LETTERARIA RISERVATA

Direttore responsabile: G. POLVANI

Tipografia Compositori - Bologna

Questo fascicolo del *Supplemento* è stato licenziato dai torchi il 28-XII-1954





